Westinghouse

ELECTRIC AND MAN'F'G CO.

Pittsburg Pa.

U.S.A.

WESTINGHOUSE

Electric and Manufacturing Co.

PITTSBURG, PA., U. S. A.

MACHINERY AND APPLIANCES

FOR

CENTRAL STATION

ARC

AND

INCANDESCENT LIGHTING,

AND FOR

POWER.

MOSS ENGRAVING CO.

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ELECTRICITY is in its infancy." This expression is often heard, but one has only to look at the marvellous growth of the business of supplying electric light and power from Central Stations to note that, in this direction at least, electricity has advanced far beyond the age of infancy, and represents, rather, manhood in its prime. At present writing, January, 1892, there are on record as in operation in the United States 1,700 Central Stations, having an aggregate capacity of 183,509 arc and 2,436,374 incandescent lights, and representing an investment which certainly cannot be less than $150,000,000.00. That such an investment should have been made during a single decade will prove conclusively to any one who doubts, if such can now be found, that Central Station lighting is a profitable business; under good management, undoubtedly more profitable than most enterprises in these days of close competition and narrow margins. We say under good management, meaning to include both wisdom in the original selection of apparatus, as well as the use of good business judgment in its subsequent operation, and electric apparatus and appliances having been brought to a condition of perfection scarcely paralleled in any other mechanical industry, there is now no excuse for an inefficient equipment on which to base the hope of success. With a knowledge arising from familiarity with the state of the art throughout the civilized world, we may say that an electric-lighting plant, such as we now build, so far from being in its infancy, is equal and even superior to similar plants in the respective fields of steam engineering, water works, gas lighting, or any of the other important industries of long standing; and this whether considered from either a technical or commercial standpoint.

The Westinghouse Electric and Manufacturing Company may be said to have begun its extraordinary growth in the latter part of 1886, when, as pioneers in the introduction of alternating currents, they first put upon the market this, now well known, system of electric distribution. Then, the alternating system was met by the combined ridicule and opposition of practically every one connected with the electrical industry, largely, it has since been shown, on account of its radical departures from previous methods. Now, its essential principles are admitted to be the basis of every system which hopes to successfully compete under the requirements of incandescent Central Station work. The contrast of these two facts is instructive. As witness of this statement, there are now

in daily operation 975,600 sixteen-candle-power lamps and 22,730 arc lamps (the latter branch having been taken up only at a comparatively recent date), the complete apparatus representing which has been manufactured by us. We have come to believe that any company proposing to enter the business of Central Station lighting for profit, can insure that result—good management being admitted—by, and we think only by, the employment of the complete systems which we have developed. We desire to say here, that a leading factor in the development which has given our apparatus the position it now occupies, has been the hearty co-operation of the Lighting Companies, who have been our customers. Being sufficiently fortunate to secure and retain their good-will, we have been able to bring to bear a leading tenet of our policy, which is, to study carefully all the conditions, commercial and otherwise, surrounding Central Station service. A successful system, in the only practical and worthy sense of the term, is developed, not in the laboratory of the electrician, but in the station of the local company and in the store and dwelling of the customer. An early appreciation of this fact has lain near the foundation of our success.

With the universal introduction of electric lighting in cities and towns, has come the usual cheapening of methods and reduction of prices, which is a healthy part of the growth of every industry. Every local company can—and in fact, to obtain the best results, must—permit its customers to share in the decrease of prices. In doing this it may at the same time maintain and increase its own profits. The path to this end is not, however, in the investment in second-class apparatus, which to a certain extent characterized the Central Station business a few years ago. The perfection of the plant, from the boiler room to the lamp, is the prime requisite. This, good management can only supplement. No one can afford to adopt or continue the use of antiquated and inefficient apparatus in the present age of advanced methods, and it is therefore of the utmost importance to examine closely into the money-earning merits of any system claiming recognition. Elsewhere in these pages will be found a few examples, specifically illustrating the importance of the foregoing general considerations, before investigating which, we will look at the parts which go to make up our various systems.

The Alternating Current Incandescent System.

The practical retirement of the old systems of Direct Current lighting has been the necessary consequence of the commercial success of the Alternating system. A fair knowledge of the alternating system and its contrasted characteristic is therefore almost universal, but not so complete that we can forego altogether a description of its principles.

It is a well-known electrical law, that for a given amount of energy and for a given distance, the cost of copper conductors will vary inversely as the square of the potential used, line losses being equal. Hence, it is the natural interest of the investor to employ as high an electro-motive force as possible. For example; with copper wire worth 18 cents per pound, the insulated conductors to carry 100 horse-power of electrical energy to a point 2,000 feet distant, will cost $175.00, using 1,000 volts potential and allowing five per-cent line loss. If we use 100 volts potential, other conditions remaining the same, our conductors will cost $17,500.00, or one hundred times as much.

On the other hand, opposing the use of high potentials is the fact that the incandescent lamp is, it seems, commercially limited to 110 volts as the maximum pressure; hence, if we use a higher potential on our main circuits, we must provide for a means of reducing the same to 110 volts before the current reaches the lamps. Up to this time, where continuous current systems are in use, there has been discovered no commercially satisfactory way to do this. The limit of maximum pressure on continuous current circuits seems to be 220 volts, so that where a large number of lamps are to be distributed over a considerable area, the cost of the copper becomes so enormous as to be prohibitory. Even the 220 volts above referred to, which is twice the potential of the lamps, are made possible by the use of what is known as the three-wire system—a more or less complicated and, when underground, a most dangerous arrangement,—whereby two circuits carrying 110-volt lamps, are practically run in series, a third wire taking care of the number of lamps burning upon one circuit in excess of those being operated upon the other. By the three-wire system the saving in copper over the 110-volt systems is variously estimated at from 30 to 60 per-cent, the former figure representing the best disinterested authority.

The introduction of the alternating current at once wrought an entire change in the business of electric lighting, which had previously been confined to a very restricted field. This was accomplished by employing in practical form the principle of the induction coil, by which the ratio between the E. M. F. and current may be changed at any point on the circuit and to any extent desired. It is therefore possible to raise or lower the potential of our main circuits to any extent at will, and to use whatever pressure may best suit local conditions, without regard to the requirements of the incandescent lamp. Further, while the 110-volt lamp is largely used on direct current circuits, by reason of the necessity of employing as high a potential as possible, it is by no means the most efficient or economical lamp. Therefore, when the demand of the circuit for a high potential is removed, we may consider only the most efficient lamp, and this, careful experiment has so far shown to be the one requiring about 50 volts pressure.

Although the alternating system was called into existence by the pressing need of a method of distributing electrical energy over areas beyond the reach of continuous current systems, without an unreasonable investment in copper conductors, immediately after its introduction there were found to be many other advantages attendant upon its use. This is true even where the distances to be covered are so short as to make the cost of conductors an insignificant item, or even to raise the total cost of installation to a higher figure than for direct current machinery. These facts are now so well known that it is superfluous to make more than a brief statement of them.

That a company furnishing electric current for profit should be able to take advantage of all the business offered would seem to be a self-evident proposition; but while this is possible with alternating current machinery, it is also true that with the direct current system any trade outside of a small radius from the station, calls for a disproportionate additional investment, frequently so large as to offset profits to be made from the additional revenue. We can further add that in nearly every case such trade appears after the station has been started.

A most important consideration in this connection is that of the use of meters, which is discussed elsewhere in these pages at some length. If one thing is more assured than another, it is that to get the best results a Central Station must sell all its light through meters. Were this point not conceded, the persistent and long-continued efforts of those interested in the electric industry to produce a satisfactory direct current meter would be sufficient evidence to demonstrate the correctness of our statement. The Shallenberger meter for alternating currents affords advantages in this line which are entirely beyond the reach of a station using the direct current system.

Distribution by the use of alternating currents and converters is accomplished with independent circuits, connected together only at the switchboard in the Central Station, the small line loss making unnecessary and superfluous the use of heavy equalizing wires between different sections of the supply circuits. The result is that the station attendant has perfect control over all of his lines, and in the event of a break in any one of these, by reason of a storm, fire, falling trees, or other accident, he can cut out the damaged circuit immediately, without interrupting the service in any other part of his lines for an instant. With direct current systems the heavy line losses make it necessary to connect together all outside conductors into a network forming one complicated whole, any break in which interferes with the entire service of the station. Further, when two or more dynamos are in use, pumping current into the network of conductors, it is frequently the case that the whole energy of the station may be suddenly applied at the damaged point, resulting in a possible fire,

or, what is more likely, a short-circuit and burning out of one of the generator armatures.

With the direct current system the practice of thus tying together the circuits, connects not only the street mains but also the house wiring and even the lamps themselves to one complicated system. By the grounding of one of the house wires, a consumer practically constitutes his house a path for lightning, the main wires of the circuits being the rod, and the service wires to his premises, with their connection to the ground, forming the remainder of the system. The possibility, also, of another ground on the opposite side of the circuit, somewhere in the system of conductors, and the consequent flow of current through both these grounds, is not remote. The danger of fire from such an arrangement is very serious. With the alternating system the primary circuits have no metallic connection with any wires on the consumer's premises, but are in fact completely insulated from them. A lightning discharge must, therefore, seek other conductors to the earth ; and should a ground be made by the consumer himself, he is not affected by a ground on any other part of the system, since the circuit upon which his lamps are placed is separate and complete in itself, and is connected to no other.

The absence of that expensive and cumbersome device, the commutator, inherent in all direct current dynamos, nets the operating company a considerable saving in annual repairs, to say nothing of the constant attention necessary in adjusting and trimming brushes. It is proper to state that the alternating current dynamo generates but a comparatively small quantity of current, and this being taken from the armature on two smooth continuous strips of brass placed upon the shaft and called collector rings, the position of the brushes is immaterial, the only requisite being that they make good contact.

To sum up then, the advantages of the alternating current system over the continuous current system are :

1. Low cost of the complete plant.
2. The profitable distribution of current throughout wide areas.
3. The accurate measurement by meter of the current consumed.
4. The absolute separation of different circuits, and the control of each at the Central Station.
5. Freedom from danger of accident by fire and lightning, due to imperfection in the insulation of circuits.
6. Low cost of operation and maintenance.

Having taken this brief review of the system in general, let us consider more in detail the parts which go to make it up.

Constant Potential Alternating Current Generators.

TO the practical Central Station manager the accompanying illustration of the Constant Potential Alternating Current Generator will at once commend itself. The main frame of the machine is in two parts, securely bolted together, and which separate on a horizontal plane. The upper piece, or yoke, can be readily lifted off for inspection or repairs without the dynamo base being in any way disturbed. The whole design is rigid, and the pole pieces projecting radially inward are in such a position, and

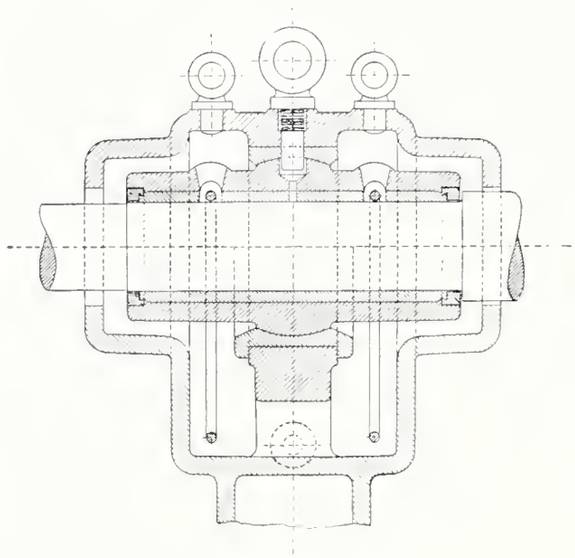


FIG. 1.—SELF-OILING BEARING.

are so proportioned, that there is almost no external field, the entire exciting current being utilized with a minimum waste of energy. Ball bearings give a perfect alignment to the armature shaft, there being a self-oiling chamber to secure perfect lubrication at each bearing.

We consider the design of this bearing of sufficient interest to give it a special illustration, the accompanying cut showing a perpendicular section through the centre of the shaft. The dynamo standard is hollow, providing a chamber for a considerable quantity of oil, which is carried up and over the

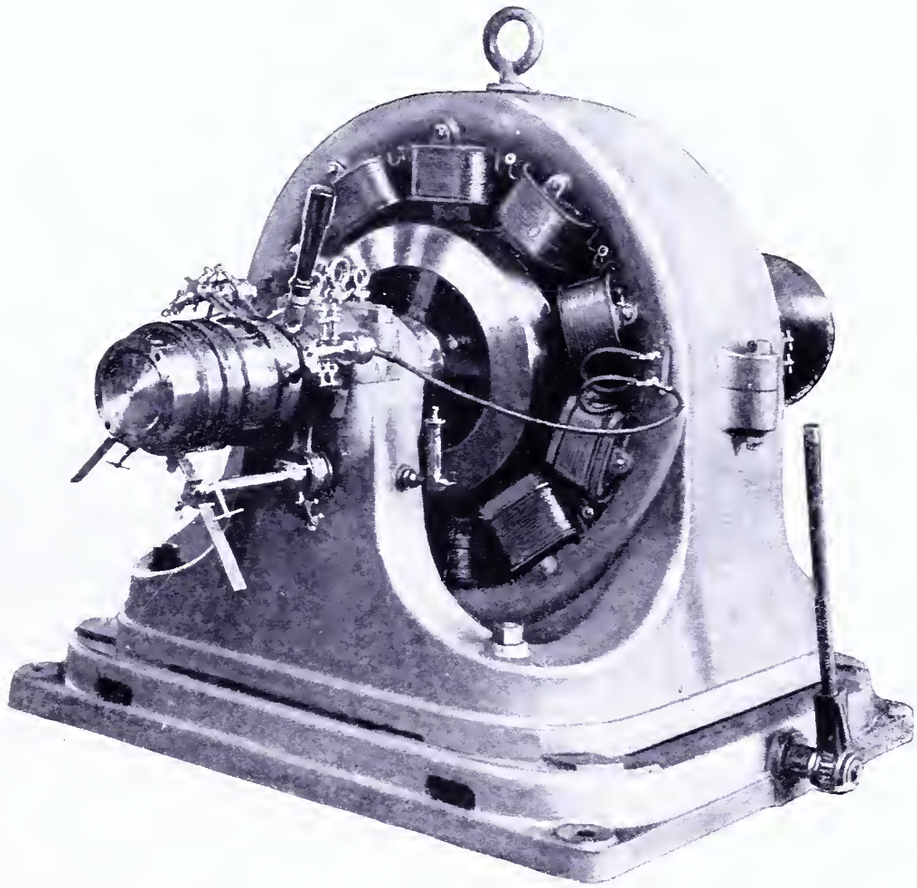


FIG. 2.—60 KILOWATT ALTERNATING CURRENT CONSTANT POTENTIAL GENERATOR.

shaft when the dynamo is in operation, by means of two loose rings of larger diameter than the shaft on which they are placed.

As will be noted, the lower portions of these rings are constantly in the oil, which adheres to them long enough for the purpose above named.

We construct generators in which the fields are excited, in part from a separate, direct current, 110-volt machine, and in part by current from the machine itself—the latter being taken from a separate winding on the armature—and we also make them entirely self-exciting. The former plan is preferable where a number of machines are to be used in one station, or where extreme flexibility in E. M. F. is desired to meet the varying conditions of load. That part of the current which comes from the armature of the alternator is directly proportional to the total output of the dynamo at all times. That is to say, when the machine is doing its heaviest work it will have a maximum field

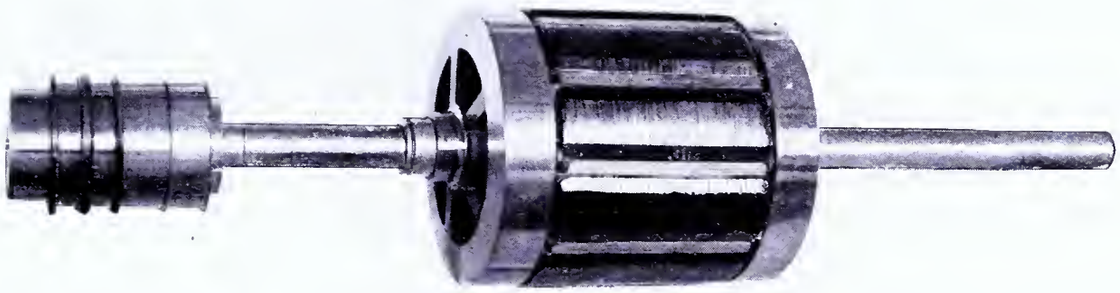


FIG. 3.—TOOTHED ARMATURE.

charge, and *vice versa*. Desiring any special E. M. F. at the terminals of the machine, we have simply, therefore, to determine the amount of current necessary to be furnished by the external exciter, and such E. M. F. will be maintained uniformly without further adjustment. A special winding on the alternator armature furnishes a small amount of current, which can be commutated, and is all that is necessary to vary the dynamo field charge, in order to maintain constant potential, as above noted.

This method of composite winding is made simple and easily effective by the employment of a toothed form of armature, which is used in this generator, and which, as representing a most marked advance over previous practice, we illustrate and briefly describe.

The illustration shows an armature complete and ready to go into its

machine. The armature is hollow, allowing most thorough ventilation, and is built of very thin steel plates having T-shaped teeth on their peripheries. These plates are placed side by side upon the shaft, and they are held in position by suitable rigid end plates. The armature coils are LATHE-WOUND, and are most carefully insulated, in addition to the standard and ordinary methods, by being wrapped with carefully prepared tape. The coils are then slipped over the T-shaped teeth and pressed into place on the armature, being completely surrounded by iron and protected thereby from any external damage. THERE IS NO WIRE WHATEVER ON THE OUTSIDE OF THE TOOTHED ARMATURE. It can be handled with ease, and even rolled on the floor without the least danger of injury. The enormous importance of this point can only be understood and appreciated by a Central Station man who has had to contend with the difficulties of handling surface-wound armatures, which, from the nature of the case, require the greatest care in boxing and shipping, and are readily susceptible to serious damage, not only when being put into place for service, but continually, from a bit of iron, a nail, or other hard substance which may get into the machine.

An increased amount of clearance between the armature and the pole pieces can be allowed when the toothed armature is used, and the danger of contact between these parts, due to the wearing away of the bearings, is eliminated.

Since there is no wire on the outside of the armature, this increased amount of clearance is obtained without an appreciable extension of the distance between the iron of the armature and of the pole pieces; consequently, the dynamo efficiency is unimpaired.

The impossibility of preventing the occasional occurrence of a short-circuit on an extensive system of conductors has been the cause of a great deal of annoyance and enormous expense to electric companies, by the burning-out of armatures. The burn-out is generally caused by the enormous rush of current, which a constant potential machine tends to give, whenever the resistance between the terminals is removed. In the design and construction of the toothed armature we have introduced an element which will largely reduce this difficulty. By reason of the proportions of iron and copper used, and their arrangement with reference to each other, the principle of the induction coil is once more called into play, for the creation of a high counter electro-motive force, whenever an excessive current is passed through its coils. Without attempting to define the exact arrangement by which this is brought about, we simply give the result. On a short-circuit, while the dynamo current will increase in quantity to approximately five times its normal amount, the electro-motive force simultaneously decreases to approximately one-fifth of its normal amount. The total dynamo output in energy is therefore approximately the same. As a result there is no

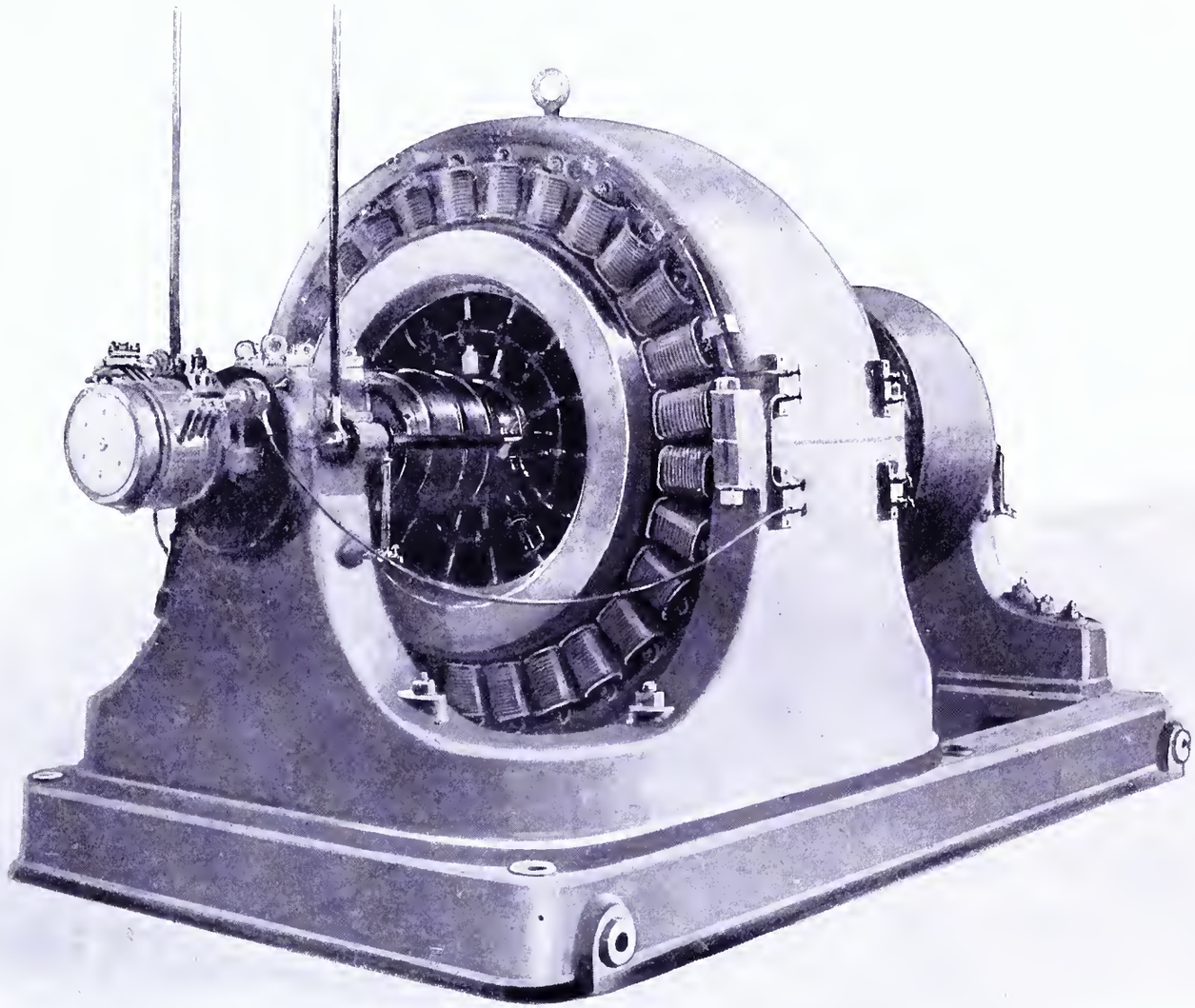


FIG. 4.—SLOW SPEED, ALTERNATING CURRENT, CONSTANT POTENTIAL GENERATOR.

burning-out of the armature, no throwing off of belts, and the liability to serious damage is largely diminished, if not altogether prevented.

We desire to call attention to the fact that this method of constructing armatures is broadly covered by patents owned and controlled by this Company; the exclusive use of them is therefore assured to purchasers of Westinghouse machinery.

By reason of the fact that the armature coils are LATHE-WOUND, they are susceptible of a very high degree of insulation. Being wound by machine, the wire is reeled directly from its spool to the coil, and is laid into place under tension. *It is absolutely free from kinks, and the insulation is never abraded, by the rubbing necessary to remove them, and always used in hand winding.* Further, after each coil is taken from its lathe it is wrapped with a specially prepared tape, and is finally coated with insulating varnish and paint. In this way insulation may be provided for currents of any required potential. In addition to the standard 1,000-volt apparatus, we are also enabled, by reason of this perfect insulation, to build machines to generate currents of 2,000, 3,000, 4,000, and 5,000 volts. On page 23 is illustrated the switchboard for handling currents of 2,000 volts and upward, to which we have given a great deal of attention. The generators for such currents are of similar type to the one shown in the foregoing illustration, the high potential currents being generated directly by the dynamo, without the interposition of any intermediate device.

In the event of damage to any coil of a toothed armature, it is only necessary to cut off such coil and slip a new one into its place, the operation requiring but a comparatively short time. By reason of this fact *it is no longer necessary for a Central Station to be at the expense of keeping a spare armature for every size of machine*, a few coils answering the same purpose and costing but little. All parts of the dynamo are made to gauge and are interchangeable.

With the rapid growth of the electric lighting industry, and the establishment of Central Stations to supply the needs of our large cities, has come a demand for a system of combined incandescent, arc, and power service, to meet which we have designed a line of generators operating at the rate of 7,200 alternations per minute, 16,000 alternations having been our exclusive practice in the past. The results accomplished by this reduction in the number of alternations are briefly as follows :

1. Following the natural course of improvement in mechanical, as well as in electrical design, has come a demand for slower belt speeds, easy running machinery, and great economy of floor space. At 16,000 alternations per minute the number of pole-pieces required, in order to materially reduce standard speeds, is so great as to make the machines heavy, cumbersome, and expensive, especially if the speeds are reduced to an extent which will permit the direct connec-

tion of the generator to an engine or turbine shaft. This latter condition is one requisite in order that the minimum floor space may be attained, and such connection is in many cases possible with the 7,200 alternation generators.

2. The activity exhibited of late in the utilization of water powers within twenty miles of a market, for electric light and power, demands a system of generators which can be used interchangeably for light and power purposes. The 7,200-alternation generator entirely fulfils the requirements of this demand, it being perfectly practicable to utilize the current for power during the day and for light during the night.

3. In large cities where the conduit system is used, the expense attendant upon the rental of ducts and the making of underground connections, to con-

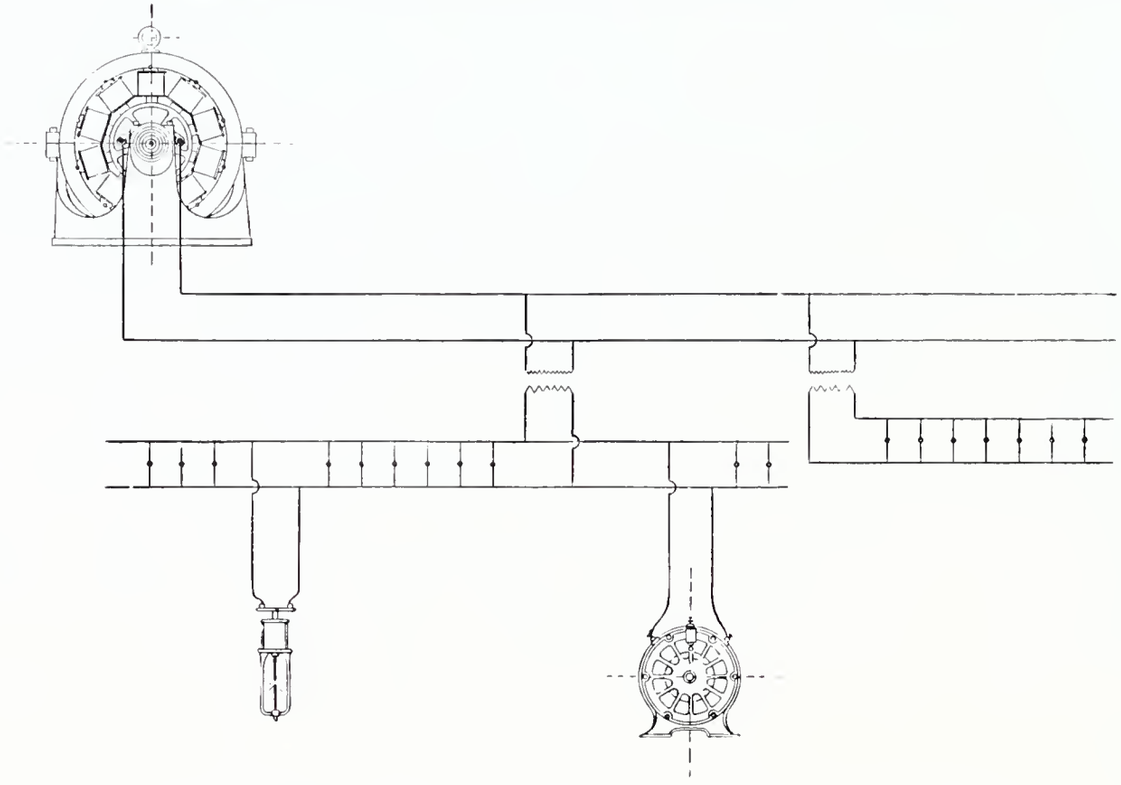


Fig. 5.—Diagram showing Incandescent and Arc Lights and Power.

sumers at various points along the line, is such as to make it extremely desirable that currents for arc and incandescent lights and for small units of power can be taken from the same circuit ; in other words, that the number of wires to be placed underground may be reduced to a minimum. While this can be done as regards both the incandescent lights and power for small motors on the 16,000-alternation system, the high number of alternations when used for arc lighting produces a slight hum in the lamps. On the 7,200-alternation system, however, a converter is introduced, and an arc lamp, satisfying commercial con-

ditions in every way, can be employed, the noise being eliminated by reason of the fact that the tone produced is so low as to be inaudible. The accompanying diagram illustrates the application of the foregoing points.

For the utilization of water powers within a radius of twenty-five miles from a market, the 7,200-alternation generator furnishes a ready method. In connection with alternating current motors of large units, and by means of an E. M. F. of 3,000, 4,000, or 5,000 volts, it becomes a very simple matter to deliver to the consumer 60 per-cent and upward of the available energy at the source of power, and this, too, without an excessive cost of copper for conductors. The enormous importance of these facts is being rapidly realized by an alert public, and the

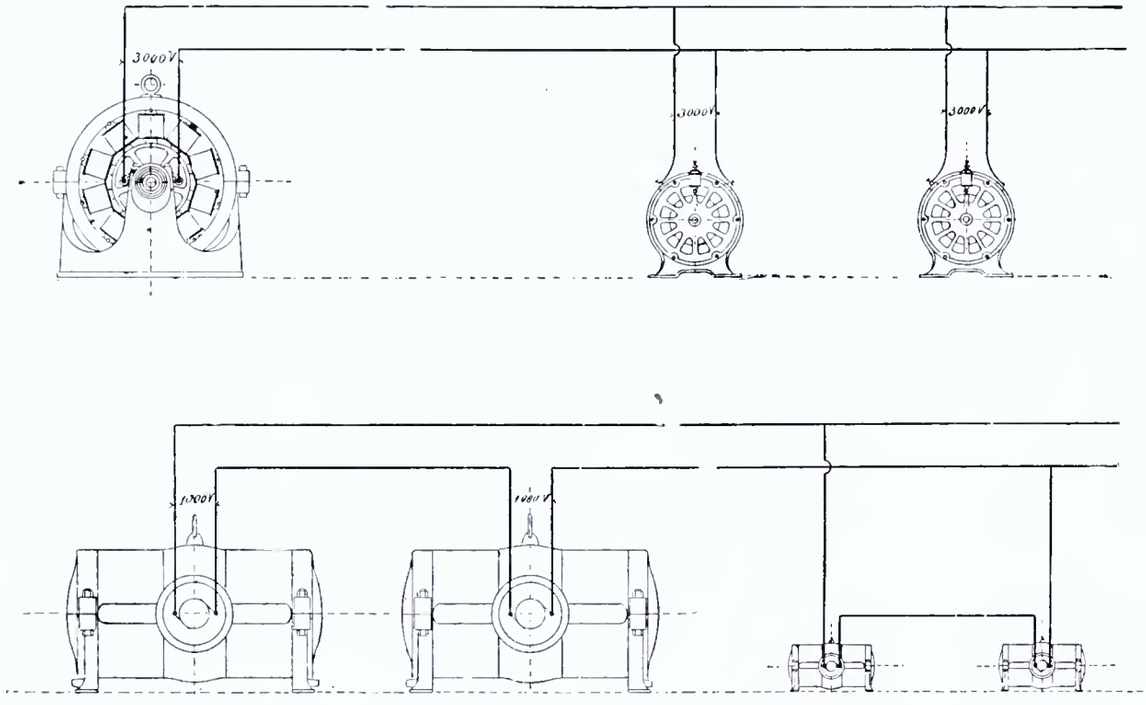


Fig. 6.—Diagram of Direct Current and Alternating Current Power Systems.

growth of this branch of our business during the last year testifies to the favor with which the system has met.

In order that the advance made by this system may be fully appreciated, we insert a diagram showing an arrangement for the long distance transmission of power, that may be considered the best modern practice up to the time of the introduction of the synchronous system. Experiment seems to show, that owing mainly to the difficulties of commutation, 1,000 volts on a shunt-wound, direct current generator is commercially the maximum limit of E. M. F. which can be allowed. Therefore, in order to increase the main line potential above

this limit, and bring the investment in conductors down to a commercially practicable point, the expedient of connecting two direct current generators in series has been resorted to, a similar arrangement of motors being made at the point of utilization of power. It has even been proposed by some to use as many as three machines in series, in order to obtain the advantages that may be gained by the employment of 3,000-volt currents ; but such arrangement would complicate still further, a plan already defective from both a mechanical and an electrical standpoint. As an easy means of comparison we have placed beside the before mentioned diagram, a diagram showing the synchronous arrangement, wherein but one generator furnishes current, not only at 2,000 volts, which is the limit of the combination direct current system shown, but even at 3,000, 4,000, or 5,000 volts, where the distance to be covered demands it. At any point on this line, where the amount of power consumed is large enough to warrant the employment of a competent attendant, motors can be taken, utilizing the main current without the interposition of any intermediate appliances. From the mechanical and electrical standpoint the advantages of the synchronous system over the direct current system are so obvious as to need little further explanation. From a commercial standpoint the expense of installing two machines is so great, where one will do, and of maintaining two sets of bearings and two high-class commutators, added to the additional cost of operating two generators, that a company doing business for profit cannot afford to consider it. The same conditions obtain at the motor end of the line also.

In brief, the synchronous system is simply the ordinary multiple arc distribution of power, which has been universally adopted for local service, wherever electrical power is sold from a Central Station. Its distinctive features lie, not in the system of distribution, but right in the machines themselves. The changes in motor and generator, however, are so radical, and the results obtained are so far-reaching in their significance, that in the long-distance system for the transmission of power in large units, it is difficult to recognize any feature of the ordinary local distribution plan. By employing an alternating current we do away with that bar to high potentials—the commutator—and by the use of the toothed armature, we are enabled to insulate to practically any extent desired. Of course, the design and construction of a high-grade, efficient, alternating current motor, has been the key to the whole situation, but this being accomplished, there is no longer any difficulty to be overcome, either mechanical, electrical, or commercial.

We desire to afford the advantages of late improvements to those who have paid us the compliment of purchasing our apparatus, and who are now using the old reliable 16,000-alternations generator with smooth body armature. With that end in view we are prepared to reconstruct any machine of the

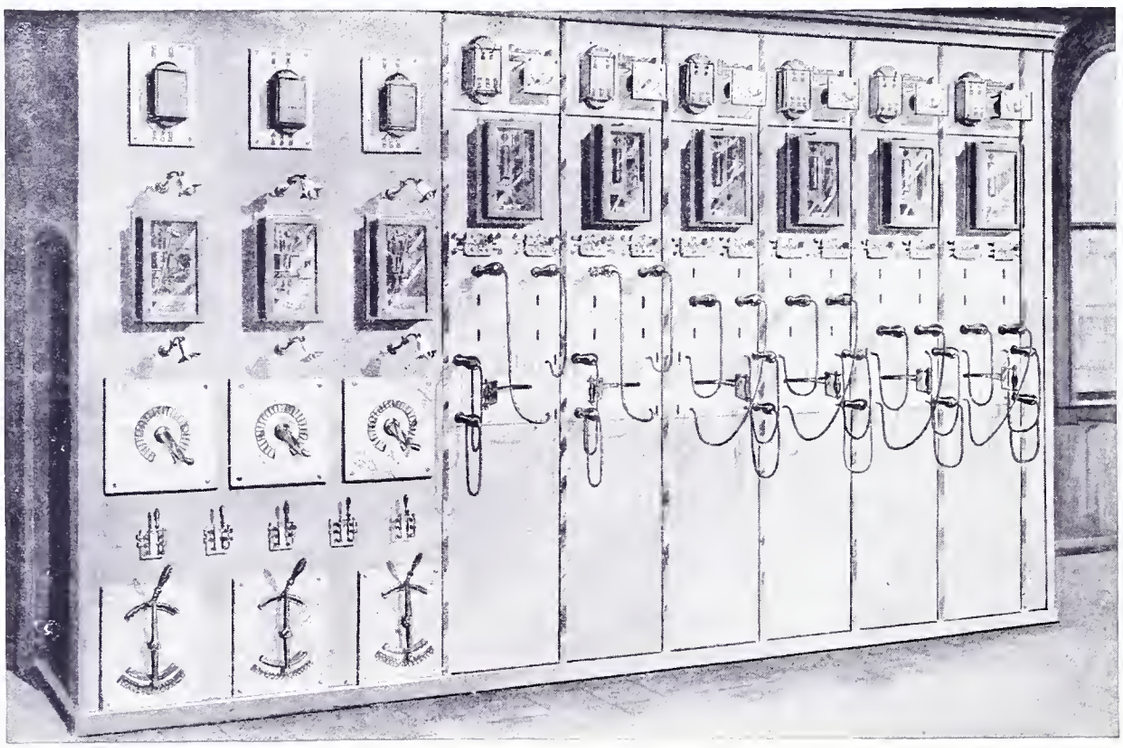


FIG 7.—STANDARD SWITCHBOARD FOR THREE DYNAMOS AND SIX FEEDERS.

smooth armature type. In such reconstruction we can increase the dynamo output from 40 to 60 per cent, according to the size of the machine so reconstructed. The advantage of increasing the capacity of a station without a rearrangement of machines, or even changing the dimensions of the dynamo foundations, will be at once appreciated. The only alterations are, of course, those relative to an increase of engine and boiler capacity, where necessary, even the latter being avoided by the use of compound engines. We desire to call the very particular attention of every one using Westinghouse alternating machinery to this matter, and we solicit correspondence on the subject.

Alternating Current, Constant Potential, 16,000 Alternation Generators.

Machine.	Capacity.	Exciting Current.		Dimensions over all.			Weight in pounds.			Speed	Pulley.	
Incandescent. Toothed Armature.	Kilowatts.	Ampères	Volts.	Length of Shaft.	Length perp. to shaft.	Height	Net.	Largest piece. Gross.	Gross Boxed for shipment.	R. P. M.	Diameter.	Face.
No. 00.	30	6	100	4′ 7½″	3′ 7¾″	3′ 4½″	2,400	1,505	2,620	2,000	12″	8″
No. 0.	45	10	100	4′ 3″	3′ 9″	3′ 9½″	3,008	1,225	3,358	2,000	12″	9″
No. I.	60	12	100	5′ 10″	4′ 2″	4′ 3″	4,777	1,778	5,266	1,650	14″	12″
No. II.	120	20	100	8′ 3½″	4′ 9″	4′ 10″	9,788	2,800	10,500	1,375	18″	16″
No. III.	240	35	100	10′ 3″	5′ 6″	5′ 8″	17,086	6,336	20,500	1,030	24″	23″
No. IV.	450	80	100	13′ 11″	7′ 10″	8′ 0″	36,000	8,938	37,500	570	44″	46″

Following the natural course of the current after leaving the generator, the next item for consideration is the

Switchboard.

The illustration shows a standard board arranged for three dynamos and six feeders. It is a well-recognized and acknowledged fact that this company has given a much larger share of attention to the manipulation of currents after they leave the generator than has any other manufacturer, and as a consequence our indicating, regulating, and controlling devices are correspondingly more complete. Only those who have to satisfy the demands of an exacting public can

appreciate the value of having all currents entirely and absolutely under control.

A brief description of the plans and purposes of the standard switchboard will suffice. At the left of the board are shown the dynamo and exciter rheostats, surmounted by an ammeter for each main circuit. To the right of the board are the feeder devices, there being one panel for each feeder. All connections are back of the board, which stands out from the wall far enough to be readily accessible from behind. Every part which has to do with the high potential currents is thoroughly insulated by non-combustible material. It is impossible to get a severe shock from the front of this switchboard, and by a simple arrangement of plugs and cables any combination of feeders may be run from any combination of dynamos. An indefinite extension of the board as to the number of dynamos and number of feeders in no way interferes with this perfect flexibility. When the station load is small, all of the supply circuits may be fed from one generator, and as the load increases one by one these circuits may be transferred to any dynamo in the station by simply setting the proper plugs and throwing over the feeder switch.

A voltmeter, with its accompanying converter and compensator, is shown above each feeder panel, and below each panel is reserved a space where, if necessary, a Stillwell Regulator may be put.

Several of these instruments, being peculiar to our system and having marked advantages, merit close attention.

Probably in no single instance, where the supply circuits have been carefully calculated on the lines of prospective custom and erected with a view of securing a uniform loss in pressure, has custom increased in exactly the localities expected, and to the extent estimated upon. The result is a variation in line loss for different supply circuits, and, assuming a uniform potential at the station, there is a consequent diversity of candle power, which will be exactly in proportion to the variation in the line loss multiplied by five—that is to say, according to the well-known law, (within the ordinary limits of service), an incandescent lamp varies 5 per-cent in candle power for every 1 per-cent variation in electro-motive force. Added to the foregoing facts, it is nearly always the case that the heaviest loads will occur on one or more circuits at a time when the other circuits are carrying but a partial load. This state of affairs still further increases the variation in E. M. F., and consequently in the candle power of lights on different parts of the system. The old method of running small wires, (so called "pressure wires") back to the station from points out on the line, in order to determine the voltage at such points, is unsatisfactory, and, if carried out in a thorough manner, very expensive. To remedy this difficulty we have introduced the Compensator and the Stillwell Regulator.

The Compensator.

The Compensator is an induction coil, so designed and adjusted that when placed on a supply circuit in the station and connected in series with the voltmeter, it will introduce an artificial inductive resistance in the voltmeter circuit, and will thereby cause a drop corresponding exactly to the drop existing in that supply circuit, at all times. The result is, that the station voltmeter indicates an electro-motive force corresponding, not to that in the station, but to that at the

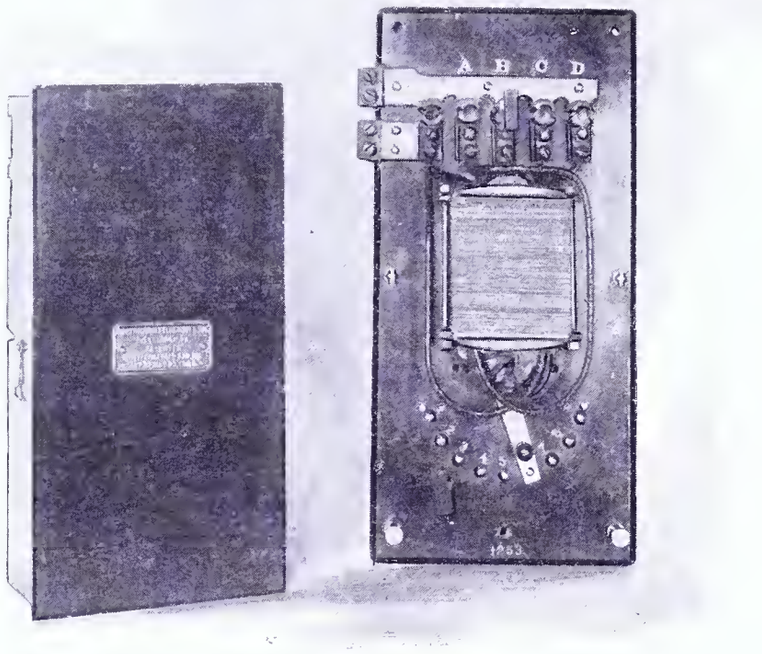


Fig. 8.—The Compensator.

lamps, distributed on the premises of the consumer. Knowing the conditions at all points on his circuits, in order to give perfect service, it only becomes necessary for the attendant to have at hand, means for equalizing the pressure. These means are found in

The Stillwell Regulator.

This instrument consists of a converter arranged with a secondary coil adjustable in length, the electro-motive force at the terminals of which is added

to the primary electro-motive force of the supply circuit, to which the instrument is attached. Within the limits of the voltage thus added, therefore, the electro-motive force of this supply circuit is subject to the most delicately shaded adjustment, independent of whatever may be the potential at the dynamo terminals. It is therefore our practice to have several supply circuits, taking current from the same generator, and although each may be operated at a different percentage of loss, the lamps are all of a uniform voltage and brilliancy.

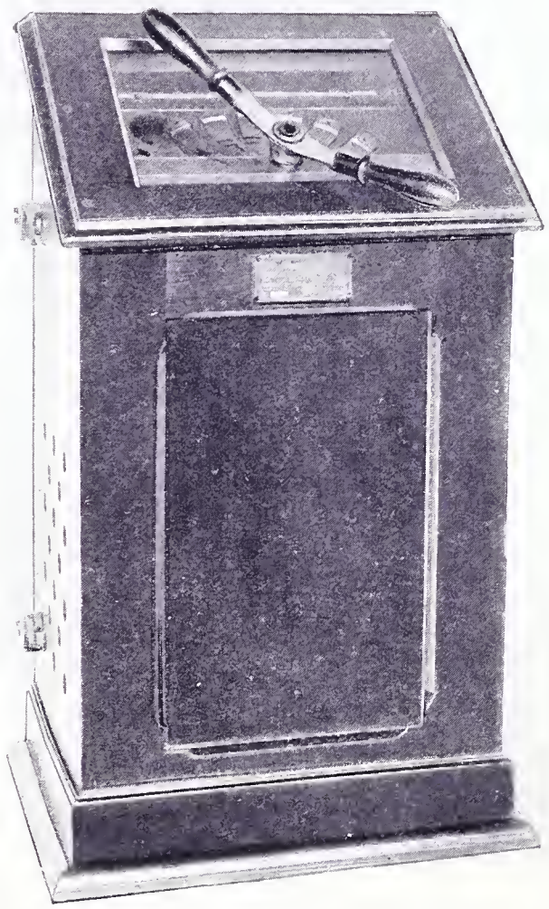


Fig. 9.—The Stillwell Regulator.

While in a large city station it is customary to equip every feeder with a Stillwell Regulator, in many smaller stations the demands of custom do not require it, nor will the extent of business done warrant the additional expense. It is, nevertheless, a fact, that in the majority of stations, however small, there is a certain amount of custom, frequently in an adjoining village, some two or

three miles away, or in an outlying mill or factory, which can be obtained for the asking, and which will yield a handsome profit if it can be reached without a disproportionate outlay for conductors. For such cases as these the Stillwell Regulator is of great value. A sample case will best illustrate its application.

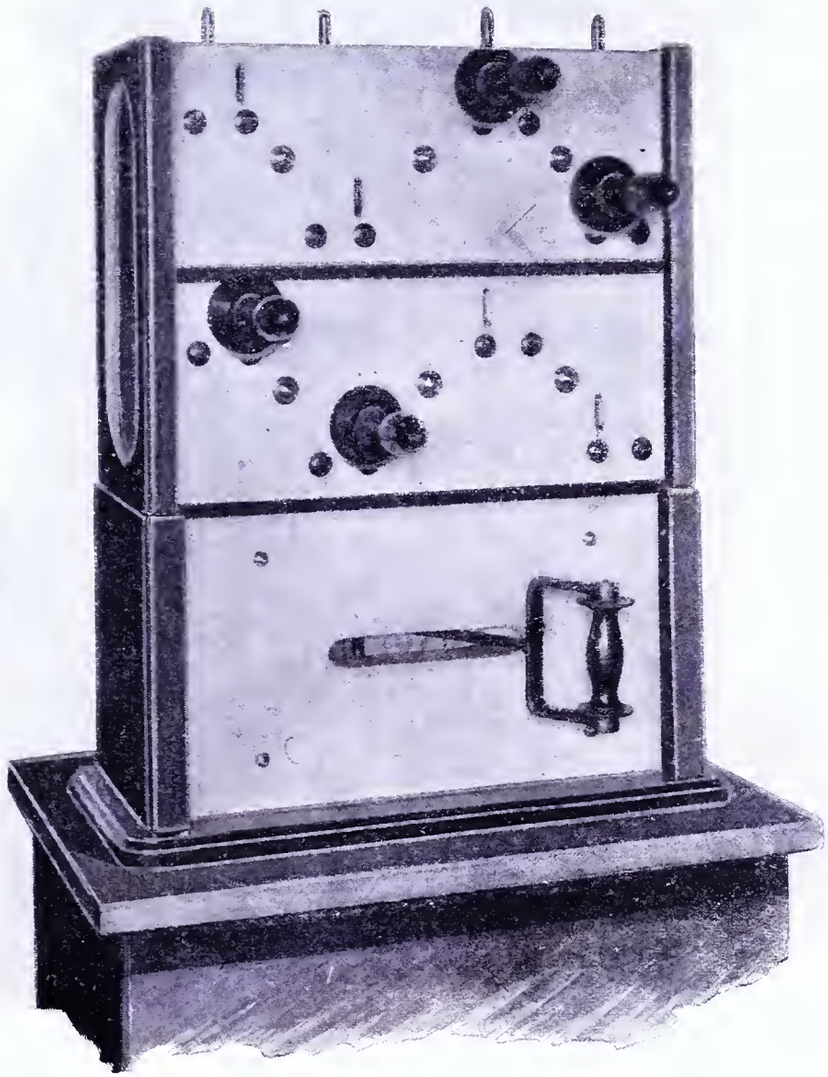


FIG. 10.—MARBLE SWITCHBOARD SECTION TYPE B.

Let us assume a station operating under ordinary conditions with a $2\frac{1}{2}$ per-cent loss in its feeders and 1 per-cent in its mains, the territory supplied being within a radius of one mile from the station. Let us further assume that there is a point two and one-half miles distant where can be secured an additional 500

lights. In order to operate them by the same dynamo, which furnishes current to the local circuits and without the Stillwell Regulator, it will be necessary to have a loss in the feeder line, not to exceed that in the local lines; viz., $2\frac{1}{2}$ per-cent. This would necessitate two circuits, equivalent to one of No. 0000 and one of No. 2, B. & S. gauge wire—five miles of each size—which, with insulated wire at 18 cents per pound, will cost approximately $4,550.00. Now let us attach a 10 per-cent Stillwell Regulator, and we can allow a loss of 10 per-cent in the long feeder in addition to that already existing in the local feeders, or a total of $12\frac{1}{2}$ per cent in all. This permits the use of a No. 2 Brown & Sharpe gauge wire, costing approximately $1,150.00. Add the cost of the Stillwell Regulator ($300.00), making $1,450.00 in all, and we have $4,550.00 − $1,450.00 = $3,100.00, the net saving effected by using the instrument.

We desire again to call attention to the fact, that the principle underlying the construction of these instruments, is dependent upon the use of the alternating current, and that the devices named are not applicable, in any way, to direct current machinery. Further, both the Compensator and Stillwell Regulator are broadly covered by patents and are assured to users of Westinghouse machinery only.

For voltages of over 2,000, we can offer our marble panel board Type "B," a small part of which is shown in Fig. 10. With this type it is impossible to get a shock from the front of the board. All the parts are very highly insulated, and by the use of the double panel, as in Type "A," the third dimension is made use of and great economy in wall area is secured.

The Converter.

THE Converter may, perhaps, be said to be the emblem of the alternating current system of distribution. On its design and construction have been bestowed the united efforts of the best electrical talent of the age. Being placed, as it is, on or near the premises of every consumer, and subject to no care or attention, it is essential that the very greatest precaution be taken to insure a durable, reliable, and safe article.

Briefly, the converter consists of two adjacent and parallel coils of wire, separated from each other by insulation and interacting wholly by induction. The primary coil receives current direct from the dynamo; the secondary coil receives no current from the primary coil, but has generated within it by induction a secondary current, entirely distinct from the current generated by the dynamo. The potential of this secondary current depends upon the relative proportions of the two coils. If the length of wire in each coil were the same, the potential of the secondary current would be the same as that of the primary current. If the length of wire in the secondary is one-twentieth of that of the primary coil, the potential of the secondary current will likewise be one-twentieth of that of the primary current. This ratio is the one employed in our standard system, using 1,000 volts primary and 50 volts secondary. It is, however, as will readily be seen, perfectly practicable to vary the ratio between the lengths of wire in the two coils, and to produce a current of any electro-motive force whatever, the limitations only being the mechanical ones of insulation and design.

That our converter has stood the test of time and secured the stamp of public approval, is attested by the fact that with nearly 1,000,000 sixteen-candle-power lamps capacity now in use, and increasing by a monthly output of over 20,000 lights, we have yet to hear of the first fatality by reason of faulty construction. Further, there is returned to us for repairs annually, less than one-half of one per-cent of the capacity of the converters in use. A large part of this remarkable record may be justly credited to our careful method of construction and insulation of the coils. This is identically the same as that adopted in the construction of coils for the toothed armature—namely, each coil is lathe-

wound, and in addition to being insulated, layer by layer, as the wire is taken from the reel, there is a final insulation, consisting of specially prepared tape, wound in a direction perpendicular to the length of the wire. This process being broadly covered by patents, all other makers of converters are obliged to adopt the plan of winding one coil directly upon the other, upon the same lathe. This, of course, is done with the wire under strong tension, and the result is to put an enormous pressure upon whatever insulation is placed between the primary and

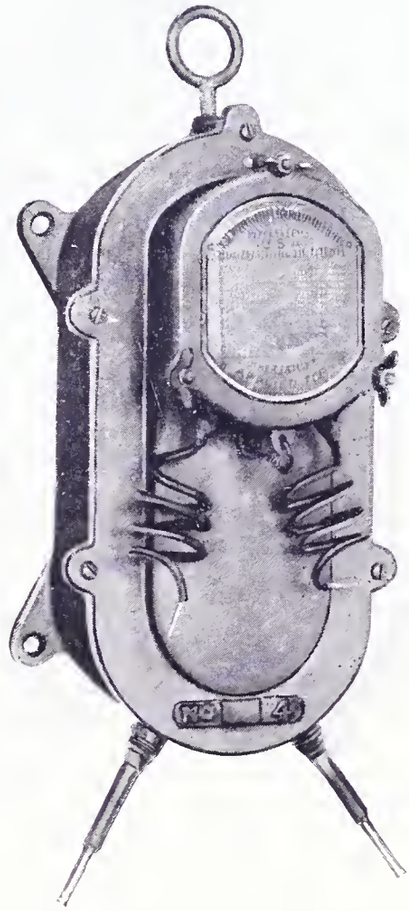


Fig. 11.—The Converter, Complete.

secondary coils. The reader will readily appreciate this if he will take a piece of string and wind it about his finger, with even a moderate uniform tension. The bearing of this point upon the life of a converter, upon the safety of the consumer who uses it, and upon the amount of repair bills can hardly be over-estimated. If one thing is more important than another, it is that the insulation between the primary and secondary coils should be absolute, and this we completely accomplish.

Two illustrations of a converter are here shown: First, the converter complete, ready for service, and, Second, the converter with the front plate and fuse

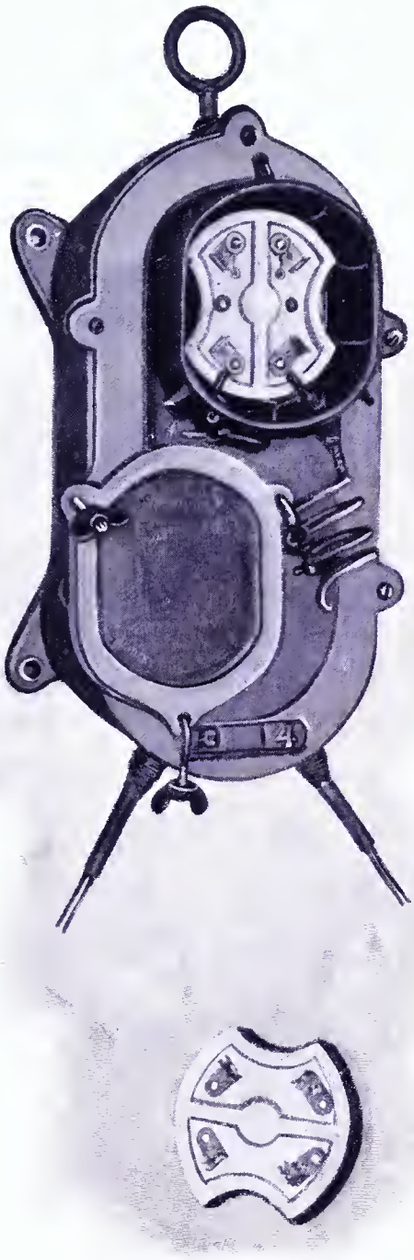


FIG. 12.—CONVERTER WITH LID AND FUSE BLOCK REMOVED.

block removed, showing the arrangement of fuses. The converter lid is attached by a chain and cannot fall when removed. Immediately beneath that, is the

porcelain fuse block, which is lifted off by the lineman, if it becomes necessary to insert new fuses. When this block is off, the converter is out of circuit and the fuses can be inserted with ease and safety. Any one who has had a fuse blow in a converter, up under the eaves of a second-story house on a rainy night, will understand the advantages of this method of fusing and the safety assured to the lineman.

Efficiency and regulation of the converter are of the utmost importance as bearing on the dollars and cents side of the operation of a station. A brief explanation of the characteristics of the converter and a definition of these much-discussed terms may not be out of place here.

The function of the converter, as has been already pointed out, is to reduce the comparatively high potential of the primary, or distributing circuit, to the comparatively low potential of the secondary, or lamp circuit. This reduction in potential is of course accompanied by a corresponding increase in current strength; that is to say, if under a pressure of 1,000 volts a current of one ampère flows through the primary coil of a converter whose ratio is 1 : 10, the current in the secondary coil will be 10 ampères and the difference in potential across its terminals 100 volts. If now the primary current be doubled, the secondary current will be doubled also, or vice versa. A converter therefore tends to reduce the potential in a definite ratio and independent of its load.

Efficiency is the relation of the converter output to the electrical energy delivered to its primary coil. A perfectly efficient converter would deliver all the energy that it received. Perfect efficiency is not attainable, however, on account of certain necessary losses which are due to two causes. First there is a loss in the coils of a converter, due to the passage of current through them. This loss varies as the square of the current flowing, and disappears entirely when there is no load on the converter. Second, there is a loss in the iron of the converter, resulting from the rapid reversal of magnetization. This loss is practically the same at all times, whether the converter is loaded or not. Its existence is indicated by a very slight flow of current through the primary of the converter when there is none at all flowing in the secondary. Leakage current is the term commonly given to the primary current flowing under these conditions. To keep down loss in the iron is usually of greater importance than to reduce that in the copper, as the former is almost a maximum continuously, while the latter is comparatively small except during the usual short period of full load. In designing our converters, therefore, special attention has been given to the minimizing of this iron loss. The iron loss depends primarily upon three things, viz.: (*a*) The inductive strength of the magnetization; (*b*) the amount of iron used; and (*c*) the quality of the iron used. The first two points have been carefully considered, and the present design and proportions have

been determined after prolonged and painstaking investigation and experiment. Aided by our long experience and the enormous output, upon which to note results, the highest state of practical and theoretical excellence has been attained. This statement is of course very broad, but it is nevertheless confirmed by authorities, and may be logically deduced from practical daily results throughout the various cities and towns using our apparatus. After spending a great deal of time and money in investigations of the third consideration, one particular grade of steel plates, made after our own formula, has been found to produce the best results. This steel is now made particularly and exclusively for us, and is so uniform in composition that *converter cores made from it will not vary in efficiency to any appreciable extent.* We consider these results as being of the greatest importance to our customers.

Perfect regulation would require that: given a constant potential at the terminals of the primary coil, the potential at the terminals of the secondary coil should remain absolutely constant throughout all variations of load within the limits of the converter capacity. Such a condition is impossible, but the importance of securing good regulation, aside from the satisfaction of rendering perfect service to the consumer, is made apparent when we consider the fact, that within commercial limits, the life of the average incandescent lamp is shortened 15 per-cent for every 1 per-cent in electro-motive force above normal at which it may be operated; that is to say, if a lamp rated at 50 volts and having a life of 900 hours at that voltage, should be run continuously at 51 volts, or 2 per-cent high, its life would be shortened to 630 hours. Every additional percentage of drop in a converter, therefore, results in so much dead loss to the operating company in lamp renewals, and the question of purchasing poor converters at a possible saving in first cost, is one which a station operated for profit cannot afford to consider.

By reason of the method of winding converter coils above referred to, it is possible to use the greatest care, and to insulate not only for 1,000 and 2,000 volts, but for much higher potentials.

In addition to the sizes tabulated on page 30, we make also a full line of converters for raising the initial electro-motive force of any supply circuit to a higher potential, where a particularly long distance is to be covered, and also for reducing the electro-motive force of 3,000, 4,000, or 5,000 volts to 1,000 volts, for the purpose of ordinary distribution where the current has been transmitted over very long distances at these high potentials. We make also special converters of any capacity and ratio of reduction.

An important adjunct to the standard commercial system is the shunt box for incandescent street lighting. The use of incandescent lamps for the lighting of streets is now very general, particularly where many trees are present which

Standard Converters.

Trade Number.	Capacity in Watts.	Primary E. M. F.	Secondary E. M. F.	Secondary Current.	Weight.	Weight Boxed.
1	250	1000	100	2½	42	54
			50	5		
2	500	1000	100	5	58	72
			50	10		
		2000	100	5		
			50	10		
4	1000	1000	100	10	83	100
			50	20		
		2000	100	10	90	107
			50	20		
6	1500	1000	100	15	110	137
			50	30		
		2000	100	15	103	130
			50	30		
8	2000	1000	100	20	153	188
			50	40		
		2000	100	20	150	185
			50	40		
12	3000	1000	100	30	165	212
			50	60		
		2000	100	30		
			50	60		
16	4000	1000	100	40	210	279
			50	80		
		2000	100	40		
			50	80		
20	5000	1000	100	50	250	325
			50	100		
		2000	100	50		
			50	100		
25	6250	1000	100	62.5	310	384
			50	125		
		2000	100	62.5		
			50	125		

would break arc light rays and cast heavy shadows. It is generally conceded that for a given amount of money the municipal authorities of a town can obtain a more general and thorough illumination of the shaded streets by the use of incandescent lights than they can by the use of arc lamps, although there will, of course,

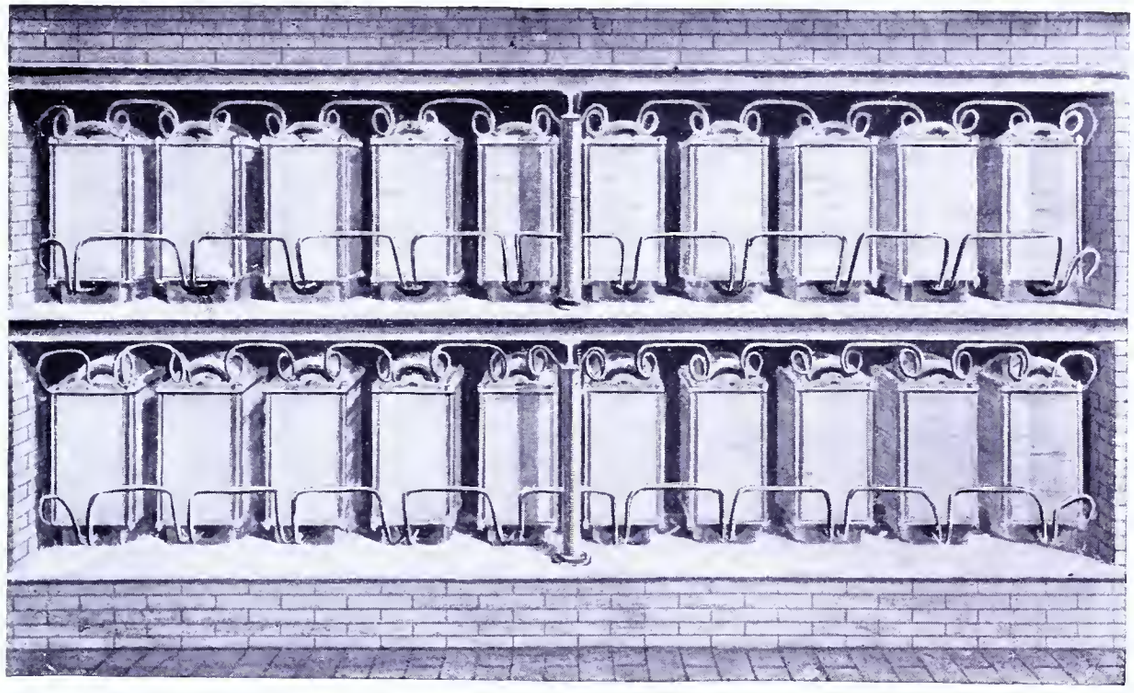


FIG. 13.—RAISING CONVERTERS.

be at no point anything approaching the brilliancy of an arc light. The shunt box is a device which is connected in parallel with each 25-candle-power 50-volt lamp, a sufficient number of these lamps being connected in series to make up the total voltage of the supply circuit to which they are attached. For example, in the ordinary 1,000-volt circuit, with 3 per-cent loss in the line and 3 per-cent loss in the converters, requiring 1,060 volts at the terminals of the machine, twenty-one 50-volt lamps will be put in series with twenty-one shunt boxes, one connected in parallel with each lamp. A percentage of current, even smaller than the leakage current of an ordinary converter, is sufficient to keep the shunt box charged, and to create a counter electro-motive force, which prevents the main current from passing through the box as long as its lamp is in circuit. Instantly upon the breaking or removal of any lamp, its corresponding box is resolved into a simple reaction coil, which takes the place of the lamp resistance, and prevents damage to the other lamps remaining in circuit. In fact, after three lamps in the twenty-one have been broken or removed, the action of the shunt boxes is to take care of more than their share of the electro-motive force, so that the remaining lamps get rather less, instead of more than their normal pressure, and are protected from any excessive currents which may occur. On the substitution of a new lamp for a broken one, the shunt box immediately resumes its former condition without any adjustment whatever. This system affords a very simple and

complete method of street lighting and one which requires but little care. One end of a series loop may be attached to the main supply circuit at any point, and the other end of the loop at any other point, not necessarily in the same part of town, it being only required that both ends of the loop shall be attached to mains, supplied by the same dynamo and connected to different terminals of the machine.

Where a smaller number than twenty-one lights is to be used, a converter to reduce the electro-motive force from 1,000 volts to that corresponding to the



FIG. 14.—STREET SHUNT BOX.

number of lamps to be used, can be employed. In view of the fact, that with the incandescent system, municipal, commercial, and domestic lighting may be all done from one dynamo and one set of supply circuits, a considerable saving both in first cost and subsequent operating expenses is easily effected by its use. Where an inexpensive and complete system is desired, this apparatus can successfully meet all requirements.

The Shallenberger Meter.

THE meter has come to be almost as well a recognized adjunct to incandescent lighting as has the lamp itself, and while, as is the case with every radical departure, the introduction of the meter system was at first looked upon with suspicion, there is now no longer any question that its use is not only advisable but essential to the proper and economic operation of a Central Station for both domestic and commercial

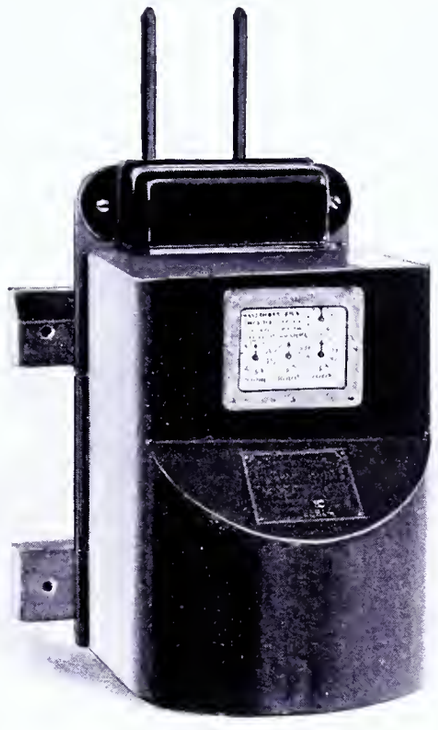


FIG. 15.—THE SHALLENBERGER METER.

service. The old time method of selling electricity, for so much per lamp per month, was a necessary condition accompanying the introduction of electricity as an illuminant, before a satisfactory meter had been devised. Now that the necessity for this condition of affairs has been removed, the complete transfer

from the contract to the meter basis, which has already progressed to such a large extent, is only a question of time, and a very short time too. The Shallenberger Alternating Current Meter, shown in the foregoing illustration, is in use to the extent of nearly one million 16-candle-power lamps capacity. It combines the advantages of accuracy, durability, simplicity, and a price which puts it within the reach of all.

The principle upon which the meter operates was introduced to the public by the meter itself, and marks a most radical departure from previous methods.

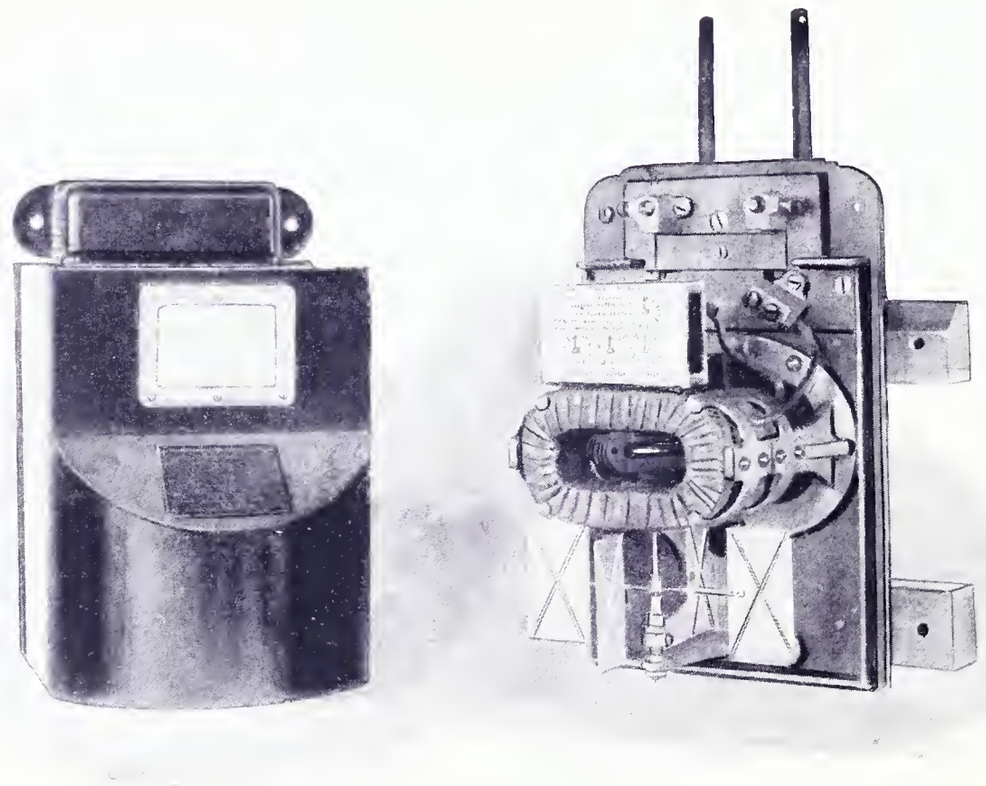


Fig. 16.—The Shallenberger Meter with Case Removed.

The meter is a direct reading instrument, recording the amount of current which is passed through it on a dial, presenting much the same appearance as that of an ordinary gas meter. The unit of measure is the "ampère hour," a term meaning the passage of one ampère of current past a certain point continuously for one hour of time. In view of the fact that a Sawyer-Man 16-candle-power 50-volt lamp consumes but from 5 to 8 per-cent more than one ampère of current, the employment of the ampère hour as a unit furnishes a ready method by which a consumer may at any time test the accuracy of his meter.

With the exception of a light train of gears, constituting the recording device in the meter, the only friction in the instrument is that between the lower

end of the upright steel spindle, which is hardened and polished, and the jewelled bearing on which this spindle rests.

We regret that it is impossible to describe, in popular terms, the action of the meter itself; but, at the risk of being somewhat technical, we will endeavor to outline its method of operation. The meter is connected directly, in series, with either side of the lamp circuit, and the ENTIRE CURRENT to be measured passes through a few turns of heavy wire, inside of which, and at an angle of approximately 45°, is placed a closed copper coil. Inside this coil again is a thin, horizontal metallic disc, mounted upon an upright spindle which is connected at its upper end with a train of recording gears and equipped near its lower extremity with a set of four aluminum fan blades.

When an alternating current passes through the primary coil of heavy wire, an alternating field of force is developed in the direction of the axis of the primary coil. At the same time alternating currents are induced in the secondary closed copper coil, and these induced currents develop another field of force in the direction of the axis of the secondary coil—that is to say, at an angle to the first. These two alternating fields of force combine to produce a resultant field; but as the alternations of the two are not coincident in time, the direction of maximum effect of the resultant field is constantly shifting or moving forward, and what is termed a revolving field is produced. The metallic disc and its spindle tend to revolve in unison with the revolving field, but a certain amount of retardation is caused by the fan blades, and as a result, the speed of rotation is in exact proportion to the volume of current passing through the instrument. The action just described depends upon a principle, which, while not as widely known, or as thoroughly understood as many others, is as absolute as is the law of gravitation itself, and it is therefore only necessary that the length of wire, the material of the disc, and the general proportions of the meter be properly designed, in order that the current passing may be at all times registered with absolute accuracy. In practice there are mechanical elements which make it necessary to allow for a certain variation. The limit of this has been fixed at 3 per-cent from zero, and every instrument made is thoroughly tested and must record accurately within this limit, before it can be shipped from the factory. The present sizes made have respective capacities of 10, 20, 40, 80, and 120 ampères. They are provided with stout iron cases, can be readily connected to the wires, and sealed to prevent unauthorized interference. An important point in this connection, is the fact that the meter may be tested, closed, and sealed in the station by the superintendent, and cannot be opened by the lineman or customer after being taken from the station. The lineman on his part, if so instructed, can, after making connections, replace and seal the small cap on the top of the instrument, so that the connections themselves cannot be tampered

with. The meter is connected directly to one side of the secondary circuit, it being immaterial to which side. Therefore, the chances of mistake are reduced to a minimum. This meter requires almost no attention, has no brushes to wear or change in tension, no permanent magnets to deteriorate, and no uncertain chemical elements to render its record unreliable. These facts place it at once and easily foremost and alone as absolutely the best meter made. This has been recognized by the London Board of Trade, which, after a most rigid series of examinations and tests, has authorized its adoption as a standard instrument. This seal of approval, coming from such an eminent body, is only an additional proof of the superiority of the meter. It is interesting to note, moreover, that the Shallenberger meter is the only one to receive the official approval of the body named.

Lamps, Sockets, Switches, and Supplies.

AS samples of the smaller details which go to make the complete systems, we illustrate a number of switches, lamps, fittings, etc., taken at random from our stock. The same careful attention to mechanical design, neatness, and finish, has been given to these smaller parts as is bestowed on the large pieces



Fig. 17.—Group of Lamps.

We furnish, through the medium of our associates, the Sawyer-Man Electric Company, of New York City, a full line of all sizes of incandescent lamps and wiring supplies. Without going into a detailed description of these, we would call your attention to two or three of our more important devices.

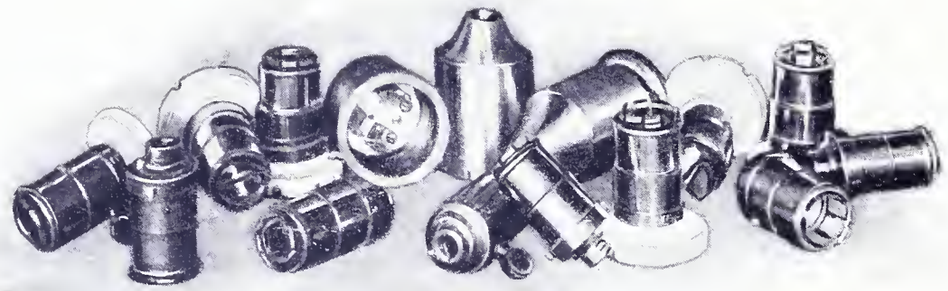


Fig. 18.—Group of Sockets.

By the utilization of the principle of self induction, we are enabled to turn up and down incandescent lamps in numbers and in degrees to suit. This is accomplished by the House and Stage Regulators, designed to be used, as their names indicate, respectively in dwellings and in public buildings. These devices are simple, durable, easily handled, and not liable to get out of order.

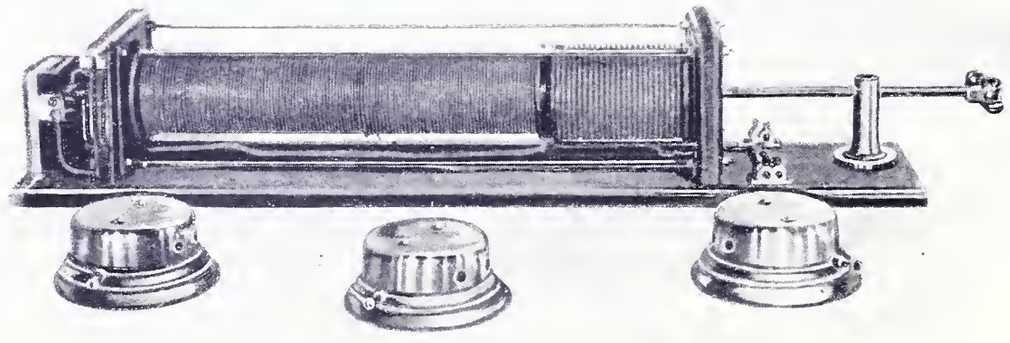


Fig. 19.—House and Stage Regulator.

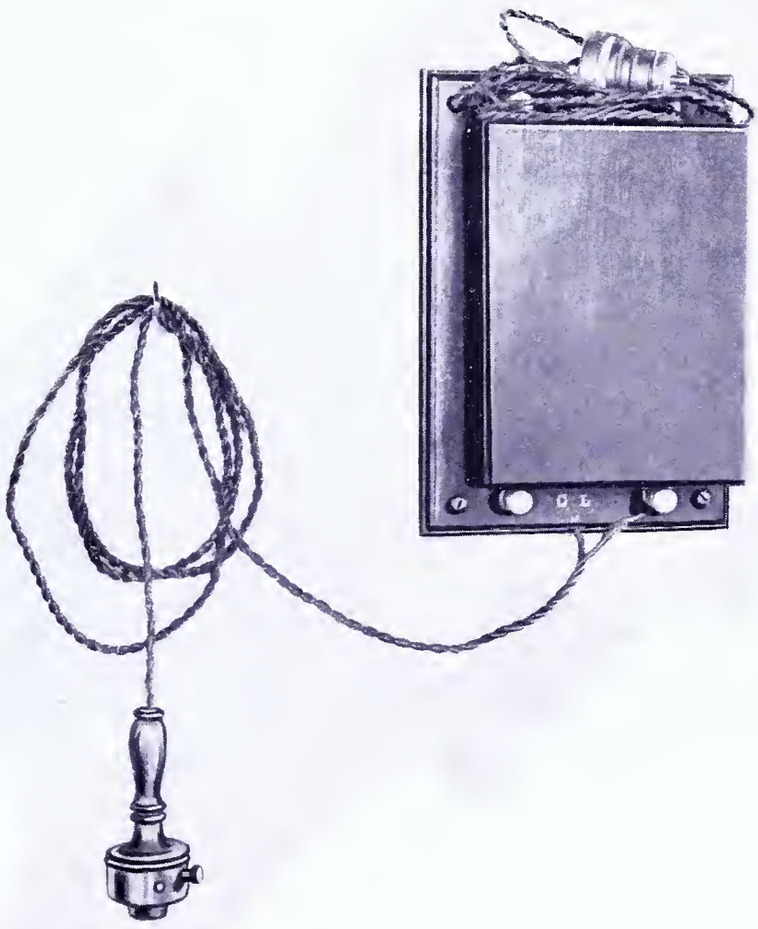


Fig. 20.—The Cigar Lighter.

The Cigar Lighter is neat and compact. Several small platinum wires, mounted on an asbestos back, are brought to a red heat instantly when the device is called into service.

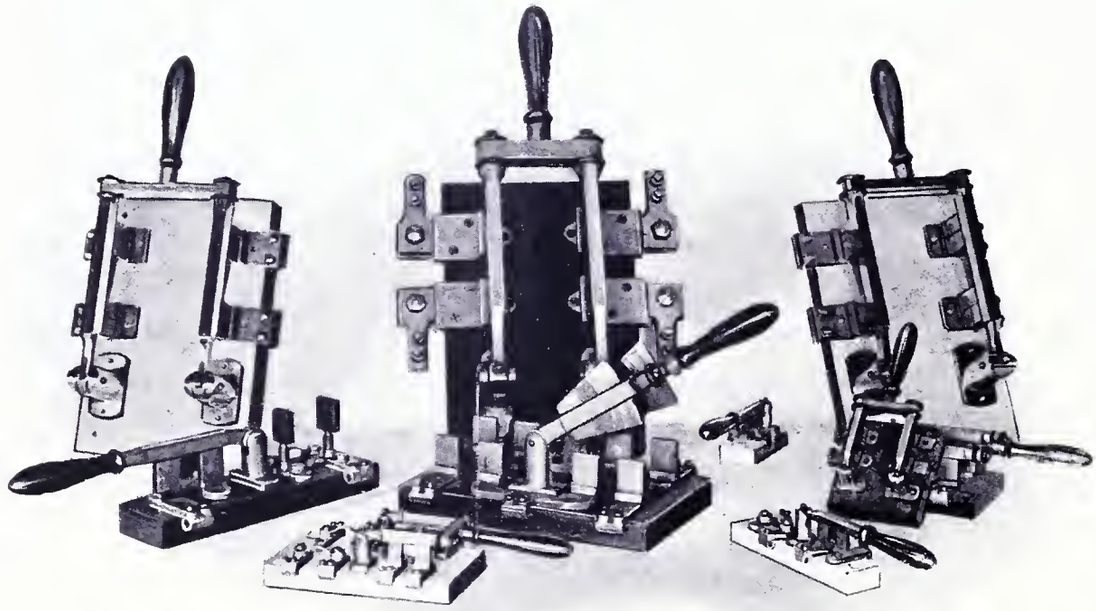


FIG. 21.—STATION SWITCHES.

Our marble and slate backed Station Switches are unexcelled in design and finish.

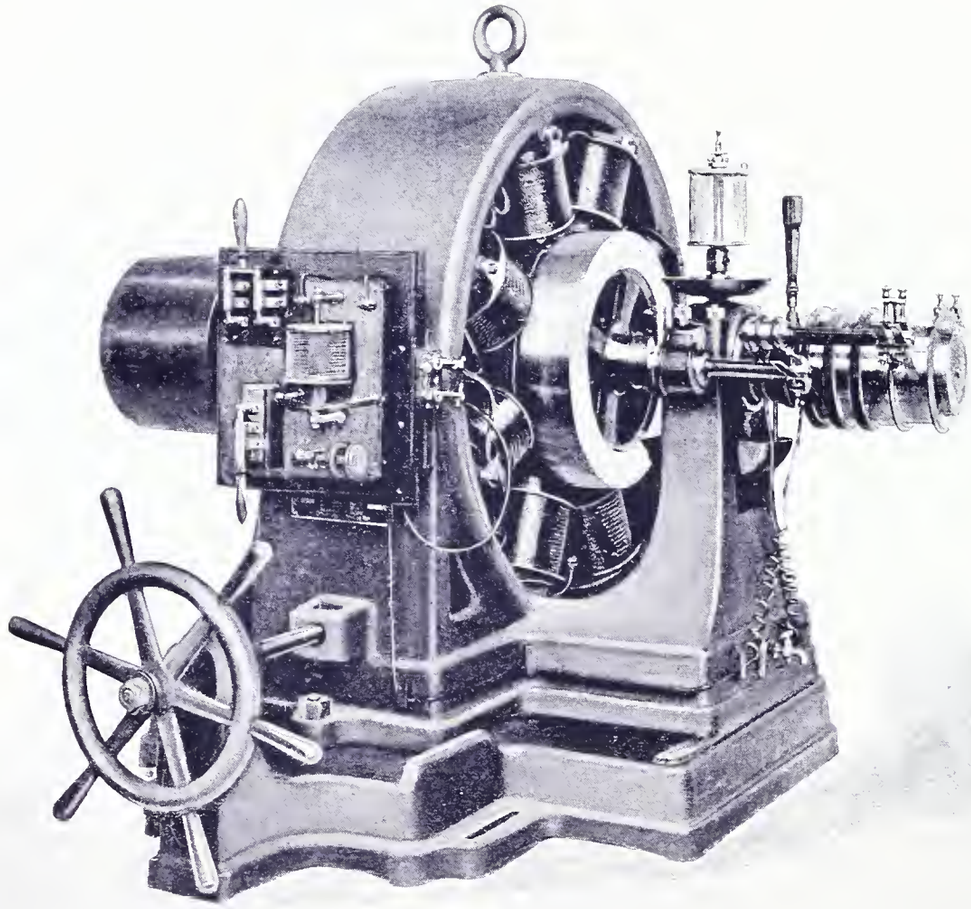


Fig. 22.—The Alternating Current Arc Dynamo.

The Alternating Current Arc System.

THIS system claims recognition, as introducing into the electric industry, several entirely new features, absolutely distinct and different from those of direct current arc systems. We can perhaps best demonstrate this fact by a brief detailed description of the various parts which go to make it up. We illustrate first the dynamo complete, and note that it has much the same appearance as has our standard incandescent machine. The same features of self-oiling bearings, toothed armature, and the absence of extraneous regulating devices, obtain in the arc as well as in the incandescent machine. The self-regulating feature in the arc dynamo is, if possible, however, in greater contrast to other existing machines, than it is in our incandescent generator. We believe that nearly all arc systems employing the direct current, lay claim to more or less self-regulation. This so-called self-regulation, by the direct current is invariably secured by some form of extraneous governing device. The principle of alternation carries with it the related principle of self-induction, to which, among others, the alternating current apparatus is indebted for many of its most valuable features. Its illustration in this instance is the attainment of strict self-regulation, not by any form of mechanism, but wholly by the effects of self-induction, and the reaction between armature and field due to a peculiar form of construction and winding. In other words, the alternating current dynamo is self-regulating in the most complete and literal sense. It is not self-regulating over some parts of its range, but over its entire range. Thus we illustrate our No. 1 dynamo, which, while burning its full capacity of sixty lights, may be cut down to a single lamp without any effect whatever upon the dynamo, and without changing the service given by the lamp remaining in circuit. When short-circuited the armature can be run indefinitely without undue heating or sparking, and without any appreciable effect upon its operation. There being no commutator, the adjustment of the brushes becomes a matter of indifference as far as their position on any individual part of the collector ring is concerned, it being only necessary that they should make good, clean contact. Serious sparking is unknown in a station using the alternating current arc dynamos.

All our alternating current generators can be run in either direction. It is, therefore, easy to place them to accommodate various arrangements of pulleys, engines, etc.

Alternating Current Arc Dynamos.

Machine	Capacity.		Exciting Current.		Dimensions Over All.			Weight in Pounds.			Speed.	Pulley.	
Arc. Toothed Armature.	Lamps. 10 Amp.	Lamps. 6.8 Amp.	Ampères.	Volts.	Length of Shaft.	Length perp. to Shaft.	Height.	Net.	Largest piece. Gross.	Gross, Boxed for Shipment.	R. P. M.	Diameter.	Face.
No. OO	25	37	5	80	4′ 7½″	3′ 8″	3′ 3½″	2400	1505	2620	1350	12″	8″
No. O	40	60	5.5	90	4′ 9½″	3′ 9″	3′ 9½″	3100	1225	3420	1000	16″	10″
No. I	60	90	4	110	5′ 10″	4′ 2″	4′ 3″	4200	1778	4900	800	18″	13″
No. II	120	175	12	110	7′ 10″	4′ 9″	4′ 10″	9723	2800	10300	700	20″	15″

One of the most frequent and serious causes of accident in the use of arc light systems has been the breaking of the circuit wires carrying the main current. These remain charged with the high-potential current, and if picked up by some unsuspecting person may be the cause of serious injury or perhaps death. As is well known, this condition of affairs has had the attention of the brightest electricians, of municipal authorities in many places, and even of State legislatures at times. Many and varied attempts have been made to secure a preventive for the difficulty. It has, however, seemed inherent in the use of arc lamps, and it has remained for the alternating current to again afford a solution of the problem.

We illustrate on page 43 what is known as the Short-Circuiting Device, and which is attached to every alternating current arc dynamo. This device provides for immediately cutting out the entire circuit operated as soon as it is broken at any point. When thus cut out, the circuit carries no current or charge whatever. To use a common expression, the wire is "dead," and it may be handled freely by any one without the slightest danger of harm. This result is accomplished *by short-circuiting the dynamo itself.* We desire to call particular attention to the fact, that it is quite impossible to short-circuit the ordinary forms of direct current dynamos, without immediate and serious damage, and, therefore, that this device is applicable *only to alternating current machines.*

By reason of the inherent ability to regulate for all variations in load, the commercial efficiency of the alternating current arc dynamo is considerably increased, the amount of power taken being in proportion to the number of lamps in circuit, all the way from full load to less than one-fifth load, with very close

approximation. This fact, coupled with the compact design of the machine and the absence of cumbersome commutators, makes it possible to obtain higher efficiency and to generate the amount of power requisite for a full arc lamp with less expenditure of energy in the steam plant.

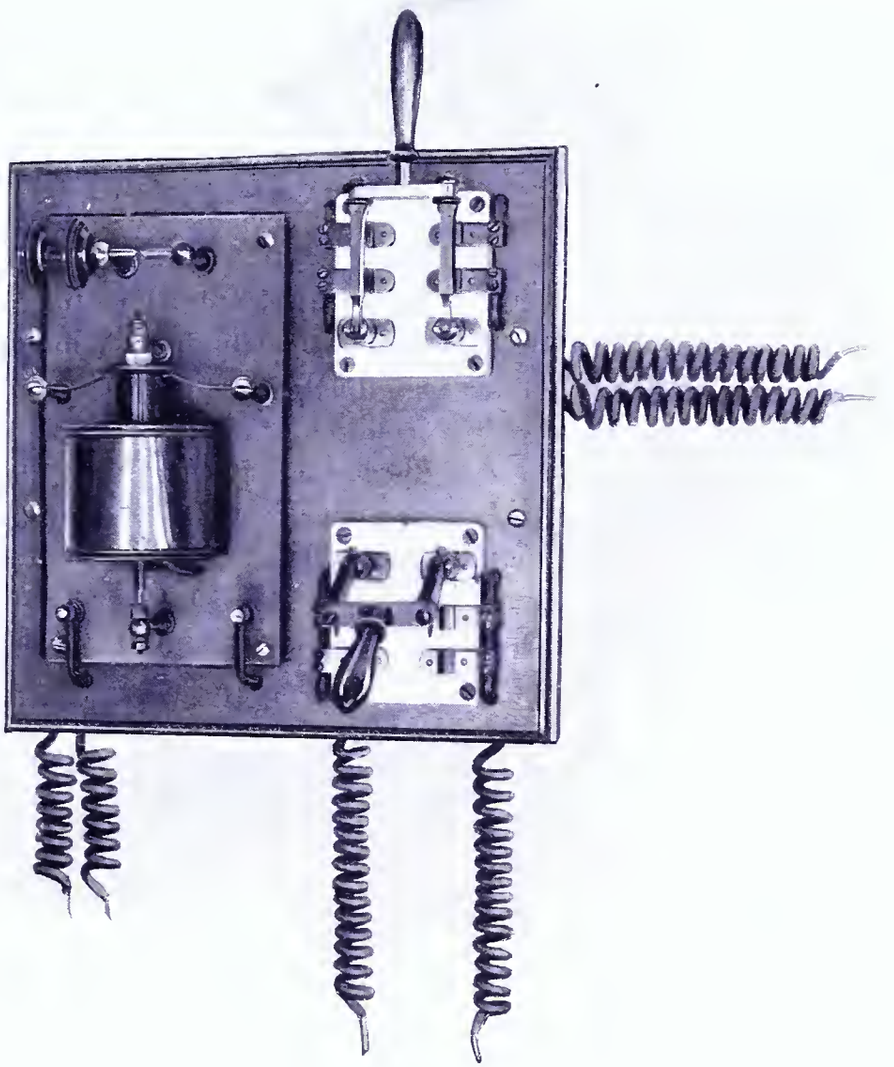


FIG. 23.—SHORT-CIRCUITING DEVICE

The Alternating Current Arc Lamp.

THE Lamp has been designed with the particular view of meeting the requirements of municipalities, under the assumption that its office is to light the greatest area with a minimum expenditure of money per annum. As is well known, owing to the existence of a hole or crater, in the lower end of the upper carbon of a direct current arc lamp, a very large per-cent of its light is thrown down in the form of a narrow cone. The natural result is to concentrate light in the immediate vicinity of the lamp itself, where a brilliant illumination is secured. Outside the base of the cone above named a very marked difference may be observed. Here, again, an inherent characteristic of the alternating current is of value. By reason of the fact that the direction of flow is changed many times per second, particles of carbon are carried to an equal extent in both directions, and there is no crater formed in either the upper or lower carbon. On the contrary, both carbons burn away equally and in the form of two rather blunt pencils or edges. As a result the rays of light are thrown in a horizontal direction, so that while in the immediate vicinity of the lamp there is not as bright an illumination secured as in the case of the direct current lamp, a much wider area is given a good general light. This we have assumed to be desirable in lighting streets, parks, and public places.

In the alternating current arc lamp all cumbersome trip-over devices, and the consequent complicated mechanism necessary for the use of two sets of carbons, have been discarded, it being found practicable, partly by reason of the above described method of burning the carbons, to use, instead of two or more small carbons, simply two flat carbons, half an inch thick, and either one or two inches in breadth. These burn from fifteen to eighteen hours in the case of the one-inch wide carbons, and in the case of the two-inch carbons from thirty to thirty-six hours with one trimming. In addition to making the lamp far cheaper, lighter, simpler, and more durable, this fact largely reduces the cost of maintenance. It is obviously necessary to trim the lamps but once every two or three nights, and the cost of two flat carbons is small compared to that of eight round carbons, necessary under the old system of double-carbon lamps. It is also apparent that in the matter of attendance, but one-half the number of lamp trimmers is needed.

Another important adjunct to the alternating current arc system is the converter. A serious objection has been urged against using direct current arc lamps where they can be readily touched or where the wires are liable to come



Fig. 24.—Alternating Current Arc Lamp.

in contact with any one. This is on account of the attendant danger of shock or injury to person. It is easy, in the case of the alternating current system, to put a converter of suitable size between one or more of the arc lamps and the

main circuit, so that the lamp or secondary circuit of the converter will be charged with but a low potential and entirely harmless. The converter, in this case, does not generally act as a reducing agent to alter the ratios of current and electro-motive force, but simply in the capacity of a safeguard. However, it also opens a field for the use of much larger generators, without introducing proportionately high potentials and the attendant risks, always accompanying the use of direct current machines of similar capacity. For example, it is the general custom in all arc systems to run all the lamps in series with the dynamo—that is to say, a single wire is run from one pole of the dynamo, and carries the entire current of the machine, successively through each individual lamp, and back to the opposite pole of the dynamo. As a consequence, if each lamp takes 50 volts, and there are fifty lamps used, the total electro-motive force of the circuit will be 50 x 50, or 2,500 volts, plus the E. M. F., necessary to overcome the resistance in the wire used—a high potential to be handled without serious risk. While some manufacturers have essayed to build larger machines, it is generally held that for ordinary use, where lamps are connected as above, a 60-light arc dynamo is quite at the limit of safety, and that the most careful precautions must surround the introduction of lamps into interiors, with a view of guarding against danger to person and property. With the alternating arc system, however, such is not the case. By the use of the converter the number of lights may be greatly increased without increasing the total electro-motive force of the line beyond a safe limit. This is brought about by making a machine to generate 30 instead of 10 ampères of current, this latter being the commonly adopted current for full arc service. Converters are introduced at desired points along the line, and the 30-ampère current is reduced to a 10-ampère current for use in the lamps. Take, for example, our 120 full arc light dynamo. If this machine were built to operate 120 lamps in series, the total electro-motive force of the line would be 120 x 50, or 6,000 volts, plus the E. M. F., to overcome copper resistance. Being designed to furnish a 30-ampère current, the total E. M. F. of the line is but slightly more than 2,000 volts, or just one-third as much, each lamp requiring at the primary terminals of its converter, but from 15 to 17 volts. It will be noted that 2,000 volts is a considerably lower potential than is used by the direct current system for the ordinary 50-light machine.

Where it is necessary to put the circuit wires underground, the increased cost attendant upon the usual multiplication of conductors, heretofore unavoidable, can be very largely saved by the use of large generators. This plan, we have seen, is easily and safely practicable where the alternating current system is employed.

Summing up, then, the advantages of the alternating current arc system, we find :

1. The dynamo is absolutely self-regulating over its entire range.
2. It is inherently self-regulating, without any extraneous devices.
3. It presents a safeguard against serious accident from breakage in circuit.
4. It permits the use of dynamos of large capacity, without a corresponding increase of potential.
5. The armature embodies all the valuable features of the toothed pattern of construction.
6. It may be run on a short-circuit without danger.
7. It does away with the introduction of the main circuit, with its high potential, into interiors.
8. It abolishes the use of complicated double carbon lamps.
9. It cheapens the cost of maintenance.
10. It furnishes a better general illumination for large areas.
11. The lamp is the lightest made.

The Direct Current System.

BOTH the theory and the practice of economics, as applied to Central Station work, show the commercial desirability of supplying power for general use, and generators, motors, and auxiliary appliances have come into almost as common use as have lighting and power dynamos. A brief description of this style of apparatus follows.

Letter Type Direct Current Generators.

Machine No.	Capacity. Generator. 125 Volt. Amperes.	Capacity. Generator. 250-500 Volt. Watts.	Capacity. Motor. 110-220 500 Volt. Horse-Power.	Speed. Approximate Number Revolutions per Minute. Generator. 125 Volt.	Generator. 250-500 Volt	Motor 110 Volt.	Motor 220-500 Volt.	Weight (pounds). Gross.	Net.	General Dimensions (inches). Length of Shaft.	Height of Machine from Ground.	Height of Shaft from Ground.	Pulley (inches). Diameter.	Width of Face.	Base (inches) Length.	Width.
E	9	1125	1	2100	2100	1900	1900	360	300	$18\frac{7}{32}$	$26\frac{1}{16}$	23	4	$2\frac{9}{16}$	$19\frac{3}{4}$	$11\frac{1}{2}$
F	15	1875	$2\frac{1}{2}$	2100	2100	1900	1900	550	470	$20\frac{7}{8}$	$28\frac{11}{16}$	$25\frac{1}{4}$	6	3	$24\frac{1}{8}$	$12\frac{1}{2}$
G	30	3750	5	2050	2050	1850	1850	1100	1000	$27\frac{1}{8}$	$33\frac{7}{16}$	$28\frac{3}{4}$	6	4	$31\frac{3}{4}$	$18\frac{1}{2}$
H	45	5625	$7\frac{1}{2}$	1550	1500	1400	1400	1950	1780	$33\frac{1}{16}$	$41\frac{1}{2}$	36	8	5	$37\frac{1}{4}$	$20\frac{3}{4}$
X	60	7500	10	1400	1400	1300	1300	2180	2000	$35\frac{7}{16}$	$43\frac{3}{8}$	$36\frac{7}{8}$	10	6	$37\frac{1}{4}$	$20\frac{3}{4}$
I	90	11250	15	1400	1400	1300	1300	3190	2990	$43\frac{3}{16}$	46	$39\frac{7}{16}$	9	7	$43\frac{1}{4}$	$23\frac{1}{2}$
B	..	..	$\frac{1}{4}$	....	....	1600	....	57	$39\frac{1}{2}$	$9\frac{3}{4}$	8	$6\frac{5}{8}$	$1\frac{7}{8}$	$\frac{9}{16}$	..	..
C	..	....	$\frac{1}{4}$	....	....	2000	....	92	67	$11\frac{1}{32}$	$10\frac{1}{8}$	$8\frac{1}{4}$	3	2	..	..
D	..	....	$\frac{1}{3}$	....	....	1850	....	168	137	$12\frac{5}{8}$	22	$19\frac{3}{4}$	$3\frac{1}{4}$	2	18	$9\frac{3}{8}$

During the past two years we have made many improvements in the design and construction of our dynamos, and have added a number of new sizes to

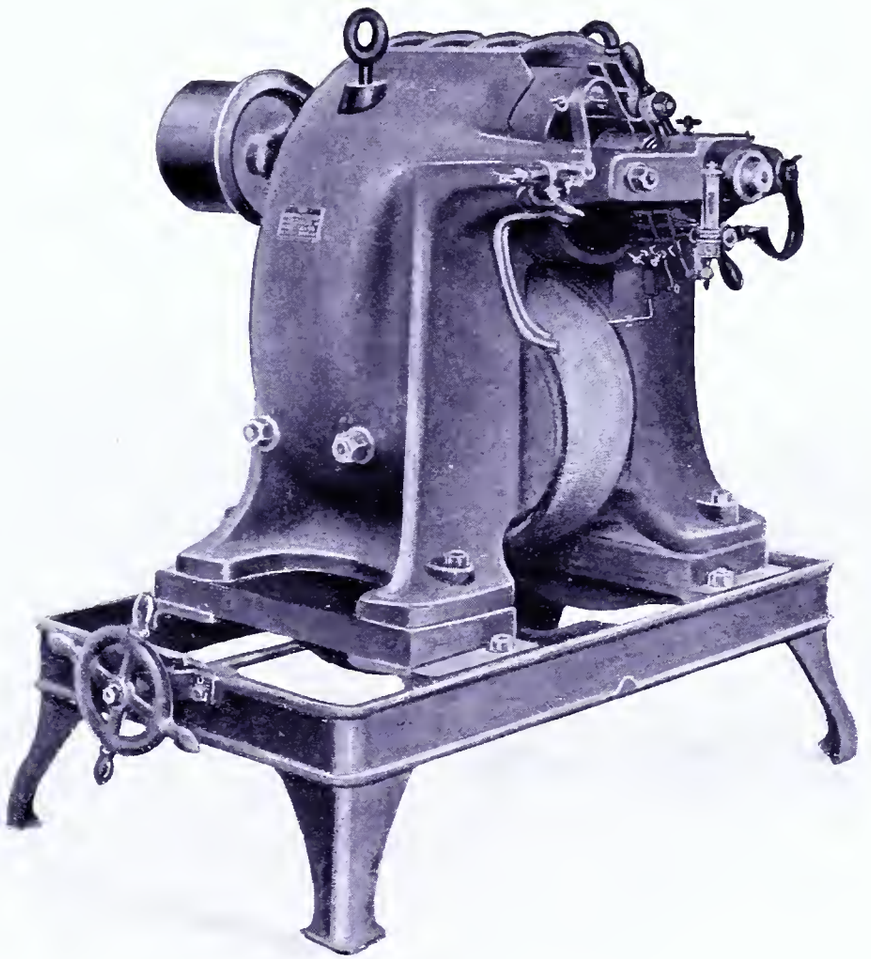


Fig. 25.—Letter Type Direct Current Generator.

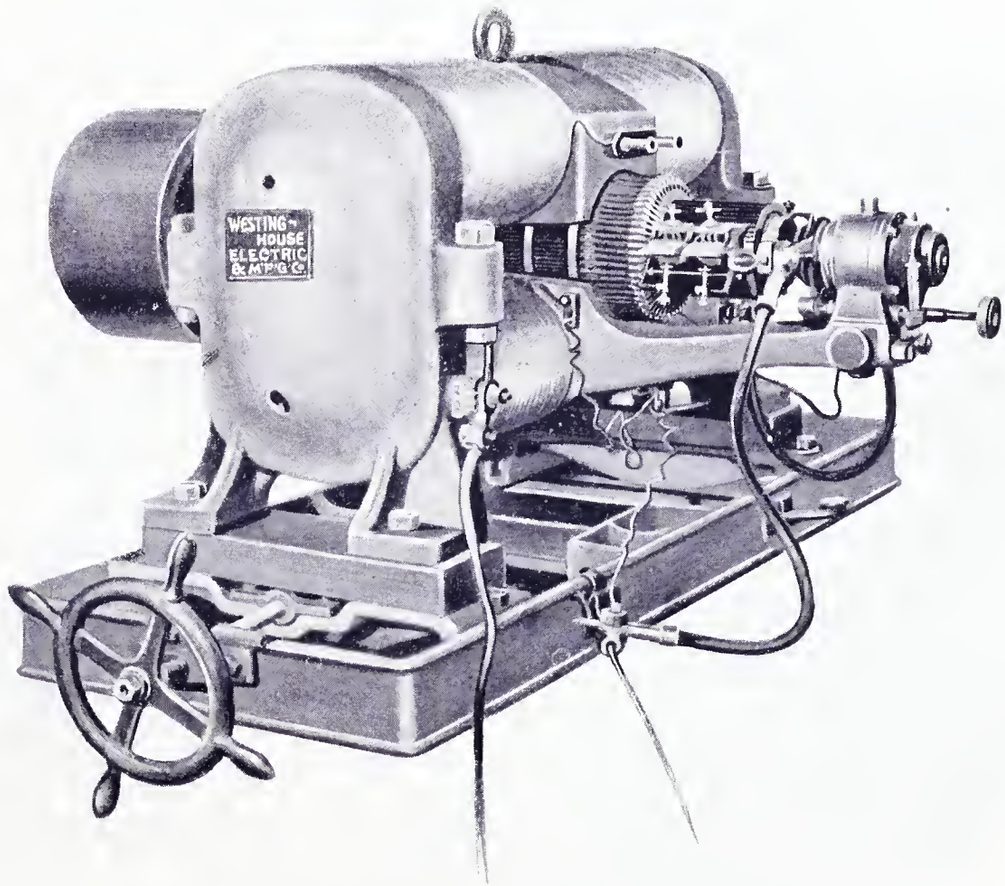


Fig. 26.—Horizo. tal Type Direct Current Generator.

the list, which cover a range of from 1,125 to 522,200 watts capacity. Nearly all sizes of our machines are built in two ways, first for generators, and second, for motors, as may be desired. We illustrate four different types, beginning with the smallest and designated respectively as the "Letter" type machines, the "Horizontal" type machines, the "Upright" type machines, and the "Multipolar" type machines.

The Letter type has its field in the form of a horseshoe magnet, with a single coil wound on the central part. The armature is of the toothed pattern, having an iron-clad surface, upon which no wires appear. The bearings are self-

Horizontal Type Direct Current Generators.

Machine No.	Capacity.			Speed.				Weight (pounds).		General Dimensions (inches).			Pulley (inches).		Base. (inches).	
	Generator.		Motor.	Approximate Number Revolutions per Minute.												
	125 Volt.	250-500 Volt.	220-110 500 Volt.	Generator.		Motor.										
	Amperes.	Watts.	Horse-Power.	125 Volt.	250-500 Volt.	110 Volt.	220-500 Volt.	Gross.	Net.	Length of shaft.	Height of Machine Including Base.	Height of Shaft, Including Base.	Diameter.	Width of Face.	Length.	Width.
9	125	15625	20	875	850	840	840	4200	3900	$54\frac{25}{32}$	$39\frac{3}{8}$	$23\frac{3}{16}$	16	10	$66\frac{3}{4}$	$21\frac{1}{4}$
13	200	25000	30	800	775	760	760	5900	5200	$61\frac{13}{16}$	$40\frac{3}{8}$	$23\frac{11}{16}$	18	10	$71\frac{1}{4}$	$26\frac{1}{4}$
17	250	31250	40	575	550	525	525	8300	7500	$68\frac{15}{16}$	$47\frac{1}{8}$	$27\frac{7}{16}$	20	12	74	$29\frac{1}{4}$
20	300	37500	50	610	550	550	500	10000	9100	$78\frac{3}{8}$	$48\frac{5}{8}$	$27\frac{15}{16}$	22	12	80	$29\frac{3}{4}$
24	375	46875	60	550	525	500	500	11250	10150	$78\frac{3}{8}$	$51\frac{5}{8}$	$29\frac{7}{16}$	24	12	85	$31\frac{3}{4}$
31	475	60000	80	485	485	450	450	14000	12800	$85\frac{1}{4}$	$52\frac{11}{16}$	$30\frac{3}{8}$	30	12	$92\frac{5}{8}$	33

oiling and the brush holder is of a most convenient pattern. This type is used up to 15 H. P., and, with the exception of the small fractional H. P. sizes, each dynamo is provided with a base, having legs to bring it up a convenient distance from the floor. The main frame, however, is insulated from the base by thoroughly dried wood blocks.

From 15,000 to 60,000 watts capacity, we build our machines of the Horizontal, consequent pole type, similar to the standard machines of this size, which we have formerly made, but without the upper arm on the commutator side. This is omitted to facilitate the handling and setting of the brushes. The handsome

and compact design and the excellent mechanical construction of this machine have commended it to all users. A constant point of commutation is maintained throughout all variations of load, thus avoiding the annoyance of shifting the brushes.

Our 75,000-watt machine is of the Upright type. This design is entirely new and is chosen to economize floor space. The generator is of the consequent pole type and maintains a uniform potential at the brushes, throughout all changes of load. It further has an absolutely constant point of commutation, a most important matter in machines of large capacity, and, as will be noted, the speed is low.

These three types of machines, when furnished as generators, are wound for 125, 250, or 550 volts, compound or shunt, as may be desired, and when used as motors for 110, 220, or 500 volts, shunt or series wound, thus allowing for

Multipolar Direct Current Generators.

Machine.	Capacity.	Exciting Current.		Dimensions Over All.			Weight in Pounds.			Speed.	Pulley.	
500 Volt D. C. Generators.	Kilowatts	Ampères.	Volts.	Length of Shaft.	Length perp. to Shaft.	Height.	Net.	Largest piece. Gross.	Gross. Boxed for Shipment.	R. P. M.	Diameter.	Face.
No. 0.	74.6	4	500	7′ 5½″	5′ 4¼″	5′ 5″	12000	4500	12600	700	26″	14″
No. 1.	111.9	4	500	7′ 10″	5′ 8″	5′ 7″	16500	4900	17500	600	30″	15″
No. 2.	186.5	4.5	500	8′ 5⅝″	6′ 2½″	6′ 2″	21150	6220	22139	525	34″	21″
No. 4.	298.4	5	500	11′ 1⅞″	7′ 5½″	7′ 4″	33750	11770	35231	450	40″	33″
No. 6.	522.2	6.5	500	14′ 4″	11′ 3″	10′ 3½″	70000	19300	71800	360	50″	46″

proper percentage of loss in circuits, when motors and generators are used upon the same system.

From 75,000 watts upward we build the Multipolar type of machines, using 4, 6, or more poles, as the case may require. The rapidly increasing demand for large units of electric power has produced a condition of trade which we have carefully studied to meet, in the construction of the multipolar machines. There are embodied certain features worthy of special mention. In the installation of very large units the steam problem becomes at once prominent, and the question of the adaptability of suitable engines with proper speed and power, must be carefully considered. Our multipolar machines are built, both

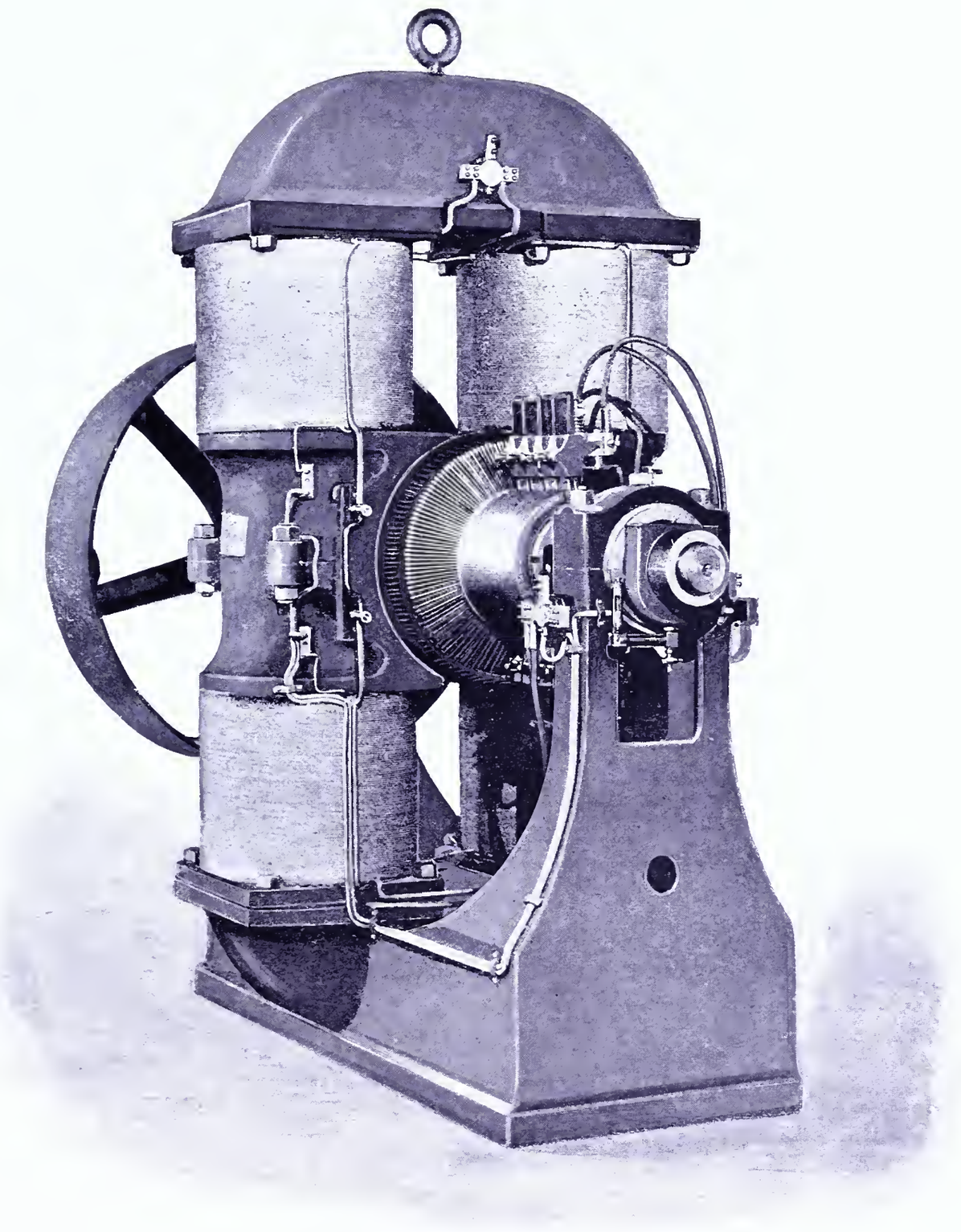


Fig. 27.—Upright Type Direct Current Generator.

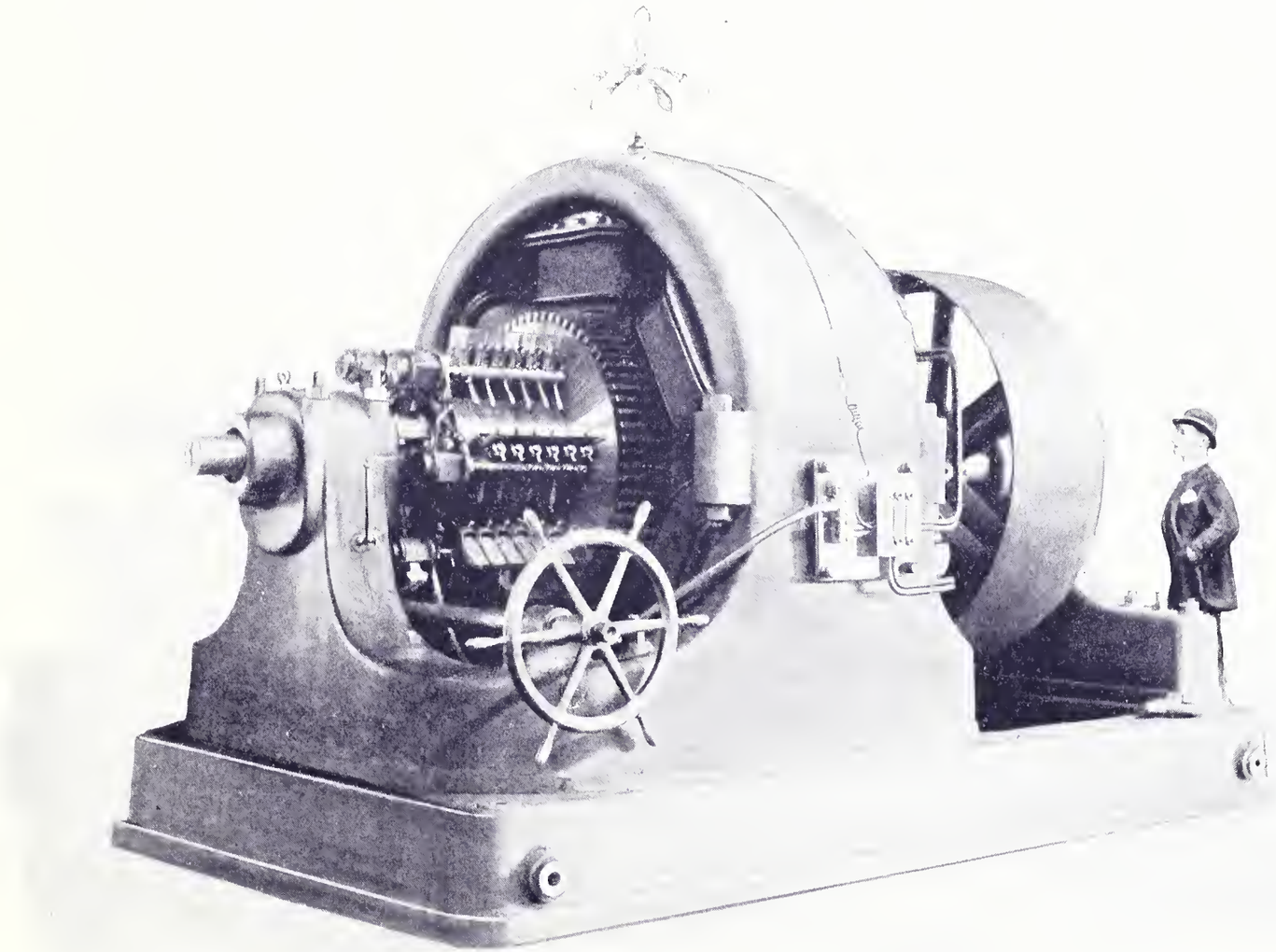


FIG. 28.—MULTIPOLE DIRECT CURRENT GENERATOR.

with outboard bearings for belt connection in the regular way, and with overhanging bearings for direct connection with engine shafts. The introduction of the multipolar principle enables us to very materially reduce speeds, and make such direct connection easy. The importance of this feature is becoming daily more apparent, and the increasing demand for the strictest economy of floor space is further evidence that the electric industry has reached its proper level, on the plane of careful business methods and good management, which alone can hope for success in these days of close margins.

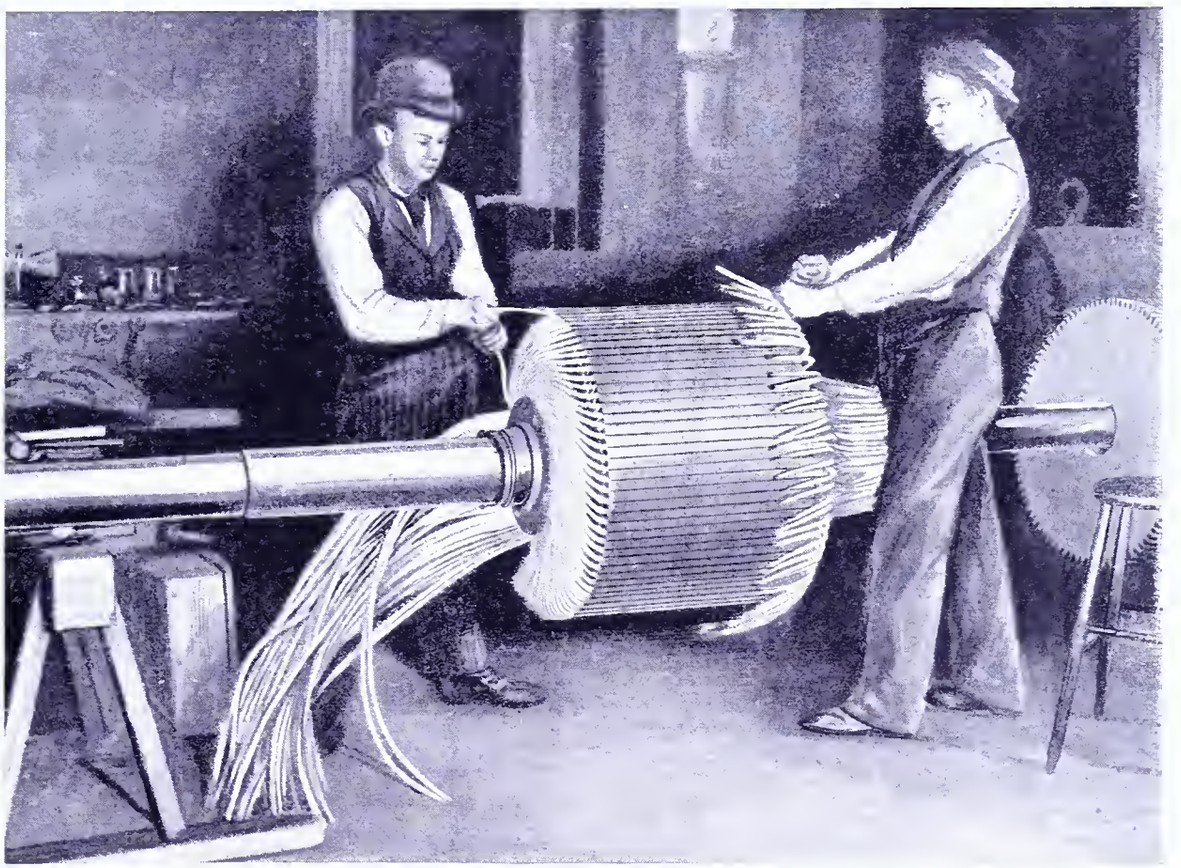


FIG. 29.—WINDING ARMATURE.

The pole pieces are made up of thin sheets of a very fine grade of steel, placed side by side and cast into one piece with the generator frame. The result is a field capable of such high magnetization with relation to that of the armature that a *variation from no load to full load does not shift the point of commutation at all.* This feature, of course, eliminates at once, the necessity for constant attention to the brushes when the load changes, avoids sparking, increases the life of the commutator and brushes, and thereby simplifies, to a great degree, the care of a station. A most marked contrast in this respect is noted between the operation of the multipolar type of generator and that of the best large generators previously offered.

We illustrate on the preceding page a corner of our factory, showing the method of winding multipolar armatures. It will be noticed that the armature core is smooth on the outside, continuously around its entire periphery, the wire being *put through holes under the surface.* This method permits the exercise of the greatest precautions in insulation, and the most careful protection of each wire from the slightest abrasion or injury of any kind. It also allows a proper leeway for expansion and contraction, so necessary where conductors for heavy currents are used. Further, of course, there being no wire on the outside of the armature, damage by contact with extraneous objects or by the bursting of band wires, etc., is avoided.

The same plan in regard to self-oiling bearings, adopted in our A. C. generators and previously described, is also used in this case. We illustrate the four types of machines heretofore described, with tables, giving the ratings as motors and generators for different voltages, and their general dimensions. We also illustrate on page 52 our $\frac{1}{30}$ Horse-Power Fan Motor, to which we attach a brief general description.

The Fan Motor.

The accompanying illustration shows our new $\frac{1}{30}$ H. P. Fan Motor, which is the result of many careful experiments and commercial tests extending over a long period. It requires but 0.3 of an ampère of current at 100 volts, and runs at the low speed of 900 revolutions per minute. Its weight is 18 pounds, and it can therefore be handled with great facility and readily moved

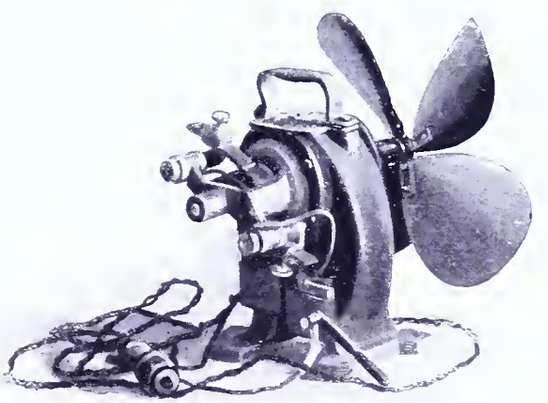


Fig. 30.—Direct Current Fan Motor.

about from place to place to suit the convenience of the user. The bearings are made of plumbago, eliminating entirely the use of oil, and the armature is grooved, allowing the wire to be placed entirely below the surface and largely reducing air resistance. The motor is very efficient and practically noiseless, which fact, together with its slow speed, light weight, high efficiency, and the minimum amount of care and attention required by it, renders it specially desirable for use in offices and stores. It is of ornamental design. A flexible cord and attachment plug is supplied with each motor, the plug being furnished to fit any style of socket as ordered.

We do not here attempt to at all outline the various uses to which electric power is rapidly being put, but before closing this paragraph we must mention the rapid strides made in the application of electricity to mining. Although serious objection has been raised by miners to the use of the electric percussion drill as offered on the market to-day, the large expense attendant upon the use of compressed air, where the distances of transmission are considerable, has created a demand for some cheaper method.

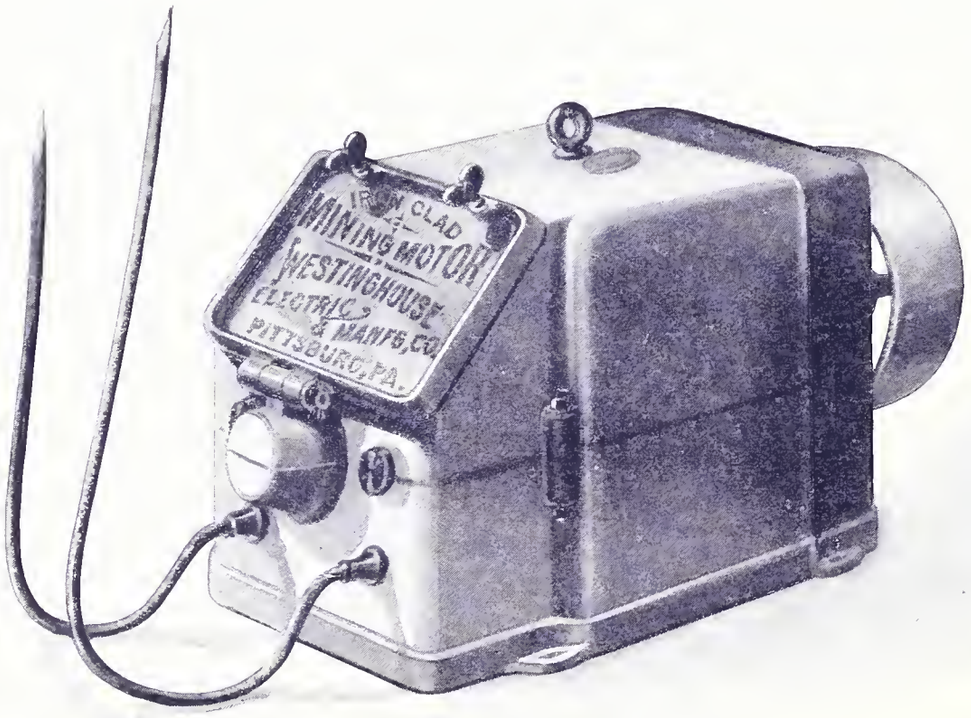


FIG. 31.—IRON-CLAD MINING MOTOR.

We illustrate our Iron-Clad, Slow Speed Mining Motor, adapted for pumps, ventilators, hoists, etc., in mines, and we also show on page 54 the same motor mounted on an Air Compressor of standard make.

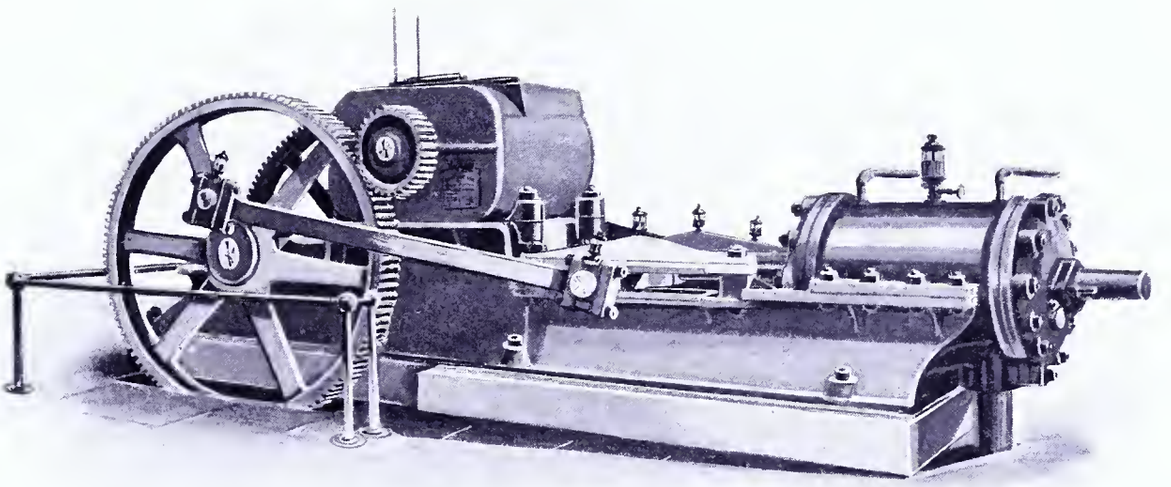


FIG. 32.—INGERSOLL SERGEANT COMPRESSOR AND MOTOR.

By means of this combination it is possible to transmit power electrically and secure all the advantages of cheap construction. At the same time the superior results pertaining to the use of pneumatic percussion drills are retained.

A Question of Dividends.

IN considering the question of investing in the lighting business and deciding upon the best apparatus to purchase, two questions present themselves:

1. Which is the best apparatus from an electrical standpoint?

2. Which apparatus will put the operating company in a position, considering capitalization and cost of maintenance, to earn the most money; or in other words, which has the greatest earning capacity?

If it made but little difference whether our apparatus was generally superior or inferior, there would be no object in spending large sums of money to obtain superiority; but it is a fact that, in obtaining the superiority which our apparatus presents, you will gain at the same time the greater money earning capacity, all the various machines, apparatus, and appliances of our make being designed primarily with this end in view. The manager of a prominent electric light company, operating apparatus other than our make, recently said to us: "Wherever I find a Westinghouse station it is earning money. I don't know why it is so, but the fact remains." We have taken occasion during the year just past to ask a very large number of companies using our systems in regard to their expenses and revenues. To the several hundred inquiries made, but one reply has been received showing a net earning of less than 6 per-cent on the capital invested. In this one case $5\frac{8}{10}$ per-cent was the net earning. The largest shown is $31\frac{3}{10}$ per-cent.

There must be a reason for these uniformly good results. A careful investigation has shown that it lies, not in any one individual characteristic, but is made up of economies in all the various costs of maintenance, which, in the long run, aggregate a handsome profit.

As an illustration of this let us take the various items of expense which constitute the yearly cost of operating a station, and consider them one by one.

1. *The Pay Roll.*—By the use of self-regulating generators, with self-oiling bearings, and a system of manipulating the currents, which requires a minimum amount of attention, the station force is reduced to the lowest limit consistent

with good practice; and the ease and convenience of handling the apparatus frequently permit the employment of lower priced labor than would otherwise be necessary. In the matter of outside attendance, in the case of arc light apparatus, 50 per-cent of the trimmer hire is saved, and in the case of incandescent apparatus the small amount of repairs necessary to converters calls for little expense in placing and replacing them. As a whole, 10 per-cent is a moderate estimate of the saving effected in the item of labor.

2. *Cost of Fuel.*—A saving of from 3 to 5 per-cent in the generator efficiency; of 1 to 3 per-cent in the converter efficiency; of 2 to 10 per-cent in the efficiency of incandescent lamps; and of 5 to 10 per-cent in the efficiency of arc lamps, will net the operating company a saving of from 6 to 18 per-cent in fuel bills for a year's time. We must, of course, bear in mind that, in addition to the excess of fuel demanded by a less efficient system, it is necessary to provide additional generating capacity at the station, to take care of an equivalent amount of light and power distributed on the consumer's premises when less efficient apparatus is used. A difference of 10 per-cent in this respect means an additional 10 per-cent investment in machinery, or, as this point is apt to be lost sight of when purchasing machinery, it comes up more frequently in the shape of 10 per-cent less custom—in other words, revenue.

3. *Oil, Waste, Taxes, and Insurance.*—Small savings can be effected in each of these items, which all swell the aggregate saving, and help to that extent towards earning dividends.

4. *Incandescent Lamp Renewals.*—We have had occasion to call attention to the fact that an incandescent lamp run continuously at 1 per-cent above its normal electro-motive force will thereby have its life shortened 15 per-cent. This statement, reduced to dollars and cents, means that for every 1 per-cent poorer regulation in his generators, lines, or converters, the Central Station manager may add 15 per-cent to the cost of lamp renewals. Therefore, the absence of the compensator, or Stillwell regulator, the use of a converter having from one-half to 2 per-cent inferior regulation, and a generator lacking in this respect from 2 to 5 per-cent, may make a difference of from 40 to 100 per-cent in the item of lamp renewals alone.

5. *The Cost of Arc Light Carbons.*—By the use of the flat carbon A. C. arc lamp, one 2-inch carbon takes the place of from 4 to 6, $\frac{7}{16}$-inch round carbons, the flat carbons costing a trifle over twice as much as do the round. Here is a direct saving, then, of from 40 to 65 per-cent in the cost of carbons.

6. *Repairs, Small Supplies, and Depreciation of Machinery.*—This is an item upon which it is difficult to estimate fairly. The failure of any part of an electric system which is relied upon to give public service, calls for not only the outlay necessary to replace the damaged part, but, if it in any way interrupts

the supply of light or power, throws discredit upon the operating company, spreads discontent and distrust among the customers, and in general, operates strongly against the maintenance and increase of custom and the securing of public favor; to say nothing of the hard work and worry called for on the part of the company's employees. We have given the most particular attention to the design and construction of our systems, with the view of reducing the percentage of depreciation to the lowest possible limit. This is a point which cannot be too strongly considered, and a difference of from 3 to 10 per-cent depreciation on the entire cost of electric equipment is a moderate estimate to put on the value of this feature.

If one thing is more essential than another, it is, that the supply of current should be at all times absolutely reliable. A company which hopes for success, in the only worthy sense of the word, can better afford to throw its generator in the scrap heap than be obliged to discontinue service for one night. Nothing is so discouraging, so demoralizing to all concerned, nothing proves such a bar to the securing of the customer's confidence, as a single failure to supply current. In our toothed armature form of construction, with lathe-wound detachable coils; in our interchangeable, independent switchboard; in our converters, constructed with the highest regard for insulation and durability, we have provided against such disastrous occurrences, safeguards which we alone have to offer, and the importance of which cannot be too highly valued.

General Station and Machine Design.

TO those of our friends who are about to build stations for supplying electricity, of one form or another, to the general public, we think it desirable here to say a few words regarding the plans which they will adopt.

Our first advice is, DO NOT BUILD YOUR STATION TOO SMALL. In explanation it is well to state that, of the many hundred companies who have purchased and installed apparatus of one or more of our various systems during the last five years, over 35 per-cent have increased the capacity of their station machinery after the original complement was purchased, and over 20 per-cent have increased more than once, some of them as many as six and seven times. In a great majority of cases it has been expected that the original outfit would be sufficient to meet the demands of trade for some time to come. It is necessary to bear in mind in this connection, that a great many of the stations which have not increased their capacity, have only been in operation from a few months up to one year, so that for stations in operation two years and over, the number of those that have increased is certainly over 70 per-cent. It is frequently the case that when a company is organized, the matter of securing large or small accommodations presents no obstacles, while after the station has once been established, property rises in price and it is difficult or even impossible to spread in any direction.

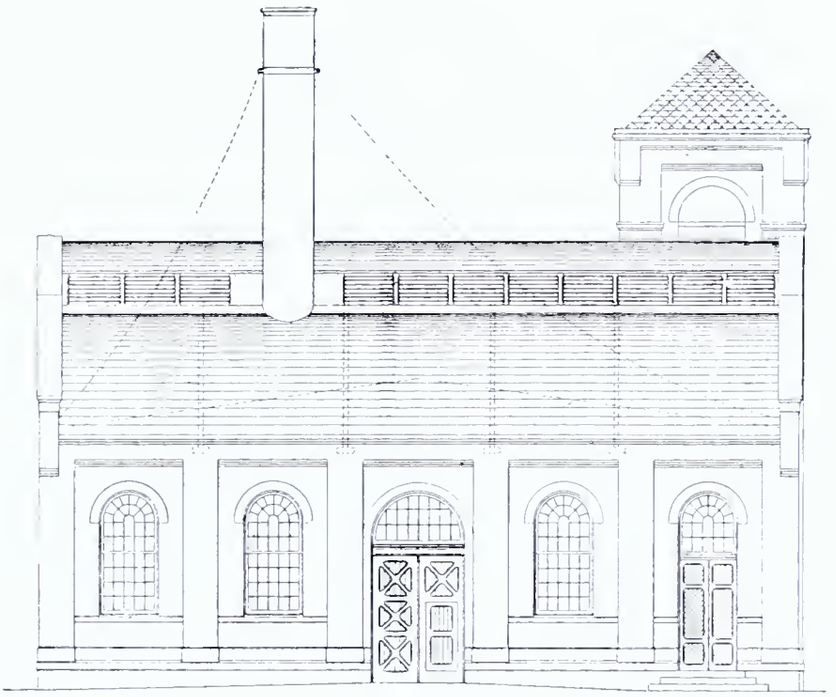
We illustrate, as a suggestion, the outline plan of a station having an initial capacity of 2,000 incandescent and 60 arc lights, with room for additional equipment, and with the building so arranged as to permit further extension if desired. This plan, of course, will be subject to modifications according to local circumstances, but the best policy will not cramp machinery into a smaller space.

For large stations to supply the needs of cities of the first and second class, great care should be exercised to meet the requirements of local conditions as regards fuel, water supply, and the operation of the station machinery with a minimum amount of attendance. We have devoted special attention to this

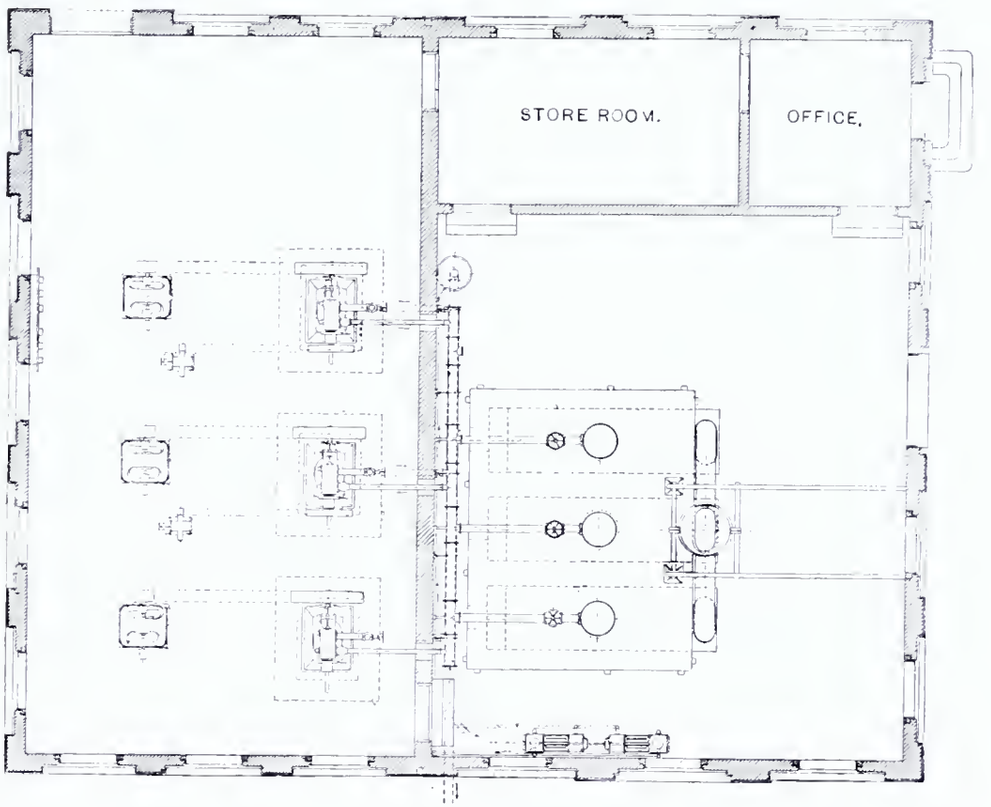
branch of the business, and solicit consultation from those who have in hand installations of the character named.

One of the most important factors in the earning capacity of a station is the depreciation or lack of depreciation in its electrical machinery. In probably no other class of apparatus is it so easy to build two machines of apparently identical construction and finish, and which will pass a severe examination as similar in all respects, and yet vary widely in quality. In a steam engine or boiler, an efficiency test, backed up by the inspection of a good mechanic, will generally give a good basis upon which to estimate the actual value of the machinery. With electrical apparatus exactly the reverse is true. While a test of efficiency and regulation is generally easy, no inspection, however careful, can safely determine the grade to which a dynamo belongs. A single example will illustrate this point. When this Company first began building dynamos they were given a capacity test, running under full load for ten hours. Then, after being examined for flaws, tests for regulation and insulation were made, and the machines passed to the packing room for shipment. It was found that, notwithstanding the most rigid and careful prosecution of this system, defects would pass the examination unnoticed. A workman in winding would perhaps allow his knife to slip and damage the insulation, afterwards covering up the weak spot with an extra amount of varnish. The result was satisfactory in a factory test, but quickly showed a flaw in general service. Subsequently our present system was adopted. This is as follows: Every part and detail of each machine is made on the piecework system of labor, and is marked with the tag of the workman who makes it. After each machine is completed, in addition to the tests above named it is given an additional test, with a current having from three to five times the potential which the various current-carrying parts are normally required to take care of. This current is generated by a dynamo and passed through converters. No light battery current is relied upon. The high electro-motive force finds out and breaks through each and every weak point in the insulation if any exist, in which case the defective pieces are charged back to the workman who is responsible for the defect. As a result, the greatest care is taken by every man to turn out nothing but perfect work, and the percentage of waste is very small. Since the adoption of the foregoing system it is a very rare occurrence for any latent defect to be found in any part shipped from our factory.

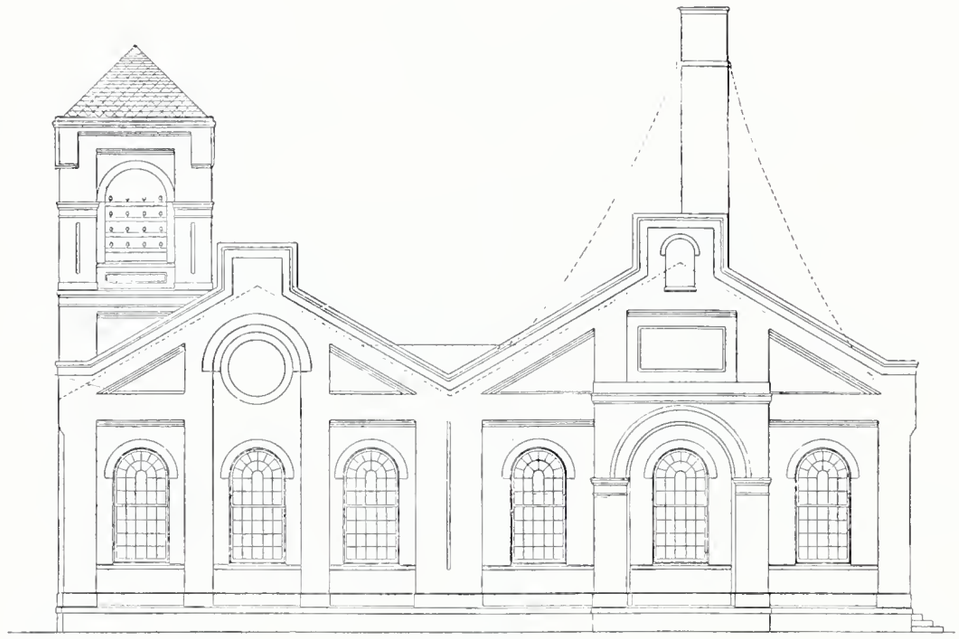
As will be noted, there is absolutely nothing in the appearance of our machinery to indicate that it has been subjected to the foregoing trial. It is only when his repair account is compared with that of stations using machinery not so tested that the manager of a Central Station realizes the benefits therefrom. The example given is only one of many.



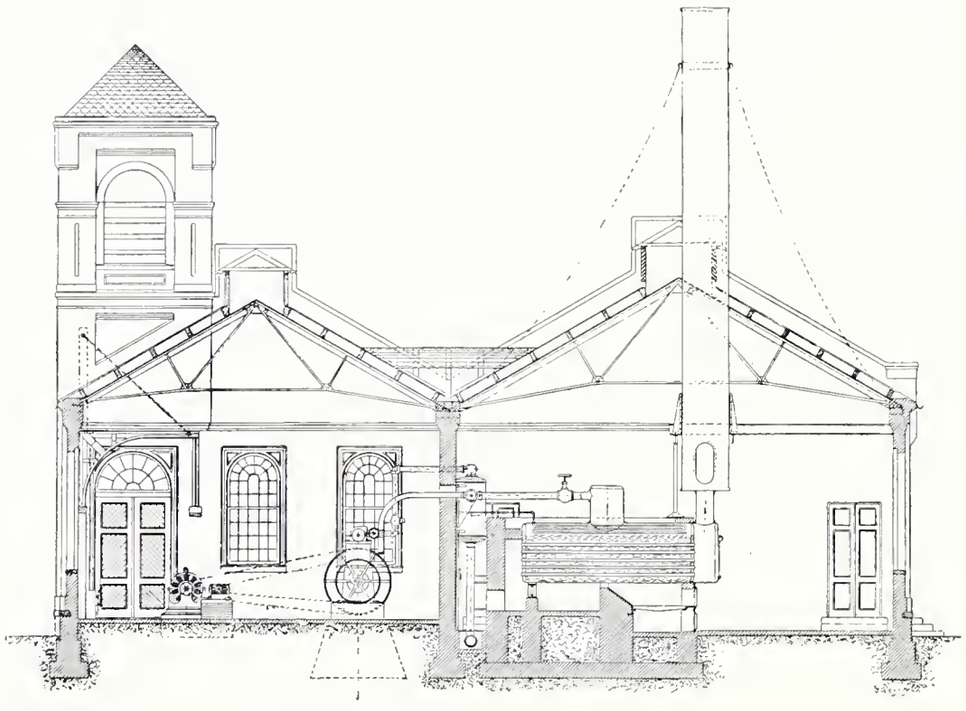
Front Elevation
FIG. 33.



General Plan
FIG. 34.



Side Elevation
FIG. 35.



Vertical cross Section
FIG. 36.

It may be interesting here to say a word in regard to our experiments with iron and steel plates for armature and converter cores, etc. We have frequently been solicited by various iron and steel men to test, with a view to adoption, this or that grade of metal. The request is generally accompanied by a statement that such and such prominent electric company has made similar tests, obtained most satisfactory results, and placed large orders for the goods. It is our policy, in every case, to make tests on material offered, but in no instance have the results compared at all favorably with those obtained from the metal manufactured specially for us and under our own particular formula. It is proper to state that only after an extended series of experiments, in which all obtainable varieties of foreign and domestic sheet iron and steel were treated, was the formula for our metal discovered and adopted.

The perfection and adoption of the foregoing features and others of a like nature have been secured at very great expense. That no outlay will be spared to maintain for our apparatus its leading position, and to improve it wherever possible, will continue to be, as ever, a leading tenet of our policy.